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Any one, who has undertaken experimental work with individual human subjects, knows that the main difficulty met with is to find subjects who are willing and can give their time to what to them in most cases must be unprofitable work. I am especially grateful to the graduate students who willingly offered their valuable time at the Chicago Laboratory. I also want to express my appreciation for the kindness of the subjects who so faithfully worked with me at the Winona State Normal School.

I. INTRODUCTION, PROBLEM, AND EXPERIMENTAL PROCEDURE

A very extensive literature has already been developed in connection with various types of learning and learning curves. A good brief summary is found in a recent article by Batson.[1] A somewhat more detailed presentation is given by Thorndike.[2]

A large number of writers have suggested what they call a typical practice curve. Bryan & Harter indicates that the sending curve for telegraphy conforms to the typical form. "The sending curve conforms approximately to the well known typical practice curve with the important difference from the curves usually obtained in the laboratory that it extends over a much greater period of time."[3] This form of the curve is one in which there is a rapid rise at the beginning indicating the rapidity of the learning in the early stages of practice. Later there is a gradual flattening of the curve indicating a progressive decrease in the speed of the learning until a point is reached where the curve is parallel with the abscissa due to the fact that a limit of improvement has been reached.

Swift, on the other hand, seems to imply that the typical practice curve is one whose form corresponds to the curve obtained by him for practice in tossing of balls.[4] This curve is the reverse of that given by Bryan & Harter. It shows a very slow progress at the beginning and a final rapid rise at the end.

Thorndike, after an exhaustive survey of various types of practice curves, says: "If any one simple form of curve, in addition to the straight line representing no change in rate of improvement, had to be chosen to represent the actual variety of facts with the least possible amount of error, . . . The rapid early rise, diminishing from the start until at the end the amount

[1] W. H. Batson, Psych. Rev., Mon. Sup., 1916, No. 91.

[2] E. L. Thorndike, The Psychology of Learning, Columbia University, New York, 1913.

[3] Bryan & Harter, Psych. Rev., 1897, Vol. 4, pp. 49 and 51.

[4] Swift, E. J., Am. Jour. of Psych., 1903, Vol. 14, pp. 204-207 and 228.

of gain is infinitesimal, is suggested by a number of practice curves."[5] Thorndike thus seems to agree with Bryan & Harter and suggests that where there is a variation from this form it often is due to a difference in the method of scoring progress. He, however, cautions against accepting any form as definite and indicates that it is possible that curves for some kinds of learning may take the very opposite form.[5]

Batson, after an experimental study of various factors in the formation of the ball tossing curve, says: "The writer believes there is no typical curve for all types of learning."[6]

It would appear, therefore, that the question as to whether there is a typical practice curve is still an open one. Whatever may be said for a typical practice curve, it is certain that variations from any typical form have been found in nearly all cases. This has lead to various attempts to analyze the factors or causes for the forms of the curves. Most of these factors are more or less hypothetical but a brief survey of the principal ones resulting from the most exhaustive and best known studies will be in keeping with the present investigation.

In attempting to explain the causes for the differences between the sending and the receiving curves for telegraphy, Bryan & Harter give four principal factors; complexity, practice, pleasure, and effort.[7] In receiving a message the complexity of the material is greater than it is in sending and the opportunity for practice at a slow rate is far less. Receiving is apt to be more fatiguing and to become a drudgery while sending is a pleasure. Both curves are in a large measure dependent upon the amount and constancy of the effort put forth for their more detailed form. The particular variations in the form of the receiving curve they hold are due to a gradual development of a hierarchy of habits from lower to higher orders.[8]

Swift has carried out a much more extensive study in so far as the variety of problems is concerned. A number of factors

[5] E. L. Thorndike, the Psychology of Learning, Columbia Univ., N. Y., 1913, pp. 255, 257.

[6] W. H. Batson, Psych. Rev., Mon. Sup., 1916, No. 91, p. 85.

[7] Bryan & Harter, Psych. Rev., 1897, Vol. 4, pp. 351-353.

[8] Bryan & Harter, Psych. Rev., 1899, Vol. 6, pp. 356, 361.

are suggested in his discussions differing somewhat with the kind of learning involved. Great emphasis is placed upon what he calls automatization of accumulated material only partially organized or learned.[9-10-11] Lack of interest, attention, and inability to measure progress are given as factors in the form of some of the curves.[9-12] Physical conditions and subjective states are given as momentary factors.[13]

Book, in his study of the curves for typewriting, seems to emphasize the subjective factors as being the principal causes for variations in the form of the learning curves. Lapses in the learners interest, attention, and effort; attention and effort wrongly applied; past experience with material learned; and the number of possible ways or directions for improvement.[14]

Thorndike has summarized the factors of improvement into four groups or conditions: external conditions, such as time of day, length of practice periods, and distribution of practice in general; physiological conditions, such as heat, light, ventilation, drugs, and disease; psychological conditions, such as interest, attention, worry, emotional attitude, and satisfaction; and educational conditions, such as order of material, approval, and criticism.[15] Thorndike shows, furthermore, that the method of measuring progress has much to do with the form of the learning curve and calls attention to the necessity of keeping in mind the method of measuring progress whenever curves from various kinds of learning are compared.[16] In speaking more directly of the changes in the rate of improvement the factors are summarized in terms of hypothetical "bonds" as follows: "We have seen how (1) the number of bonds, (2) and (3) differences

[9] E. J. Swift, Mind in the Making, pp. 209-212, 217.

[10] E. J. Swift, Psych. Bul., 1910, Vol. 7, pp. 152.

[11] E. J. Swift, Studies in Phil. & Psych. by Former Students of C.E. Garman, pp. 309 ff.

[12] E. J. Swift, Amer. Jour. of Psychol., 1903, Vol. 14, pp. 213-14.

[13] Swift & Schuyler, Psych. Bul., Vol. 4, pp. 307-310.

[14] W. F. Book, The Psychology of Skill (Monograph), pp. 99, 100, 155, 157, 161.

[15] E. L. Thorndike, The Psychology of Learning, Columbia University, N. Y., 1913, pp. 193-234.

[16] Op. cit., Columbia University, N. Y., 1913, pp. 255-261.

amongst them in ease of formation and in effect on the score, in combination with the order in which they are formed, (4) differences in the individual's general power to improve the function at different periods of the practice, (5) the relations of changed ease of formation or effect on score existing between the bonds already acquired, or those to be acquired, and any given bond, (6) the weakening of bonds by disuse, and (7) the useless overexercise of existing bonds may produce changes in the rate of improvement, and how the kind of change that any defined state of affairs of any of these seven sorts will produce can be deduced."[17]

In an experimental study of the form of the curves for typewriting, we showed that differences in the material or type of learning was a factor in the form of the curves produced. Special emphasis was also called to the part played by wrong habits or associations.[18]

The enumeration of factors given above makes it clear that nearly all the studies made on learning do concern themselves with the factors involved in the formation of the learning curve. Yet these factors are more or less theoretical at least in so far as we have any knowledge of just what part is played by each one of them. Little attempt has been made to separate these factors out and experimentally show just what influence they may have upon the form of the learning curve. Bryan & Harter not only started an interest in the study of practice curves but they also pointed out the way or method by which these various factors might experimentally be tried out. Having formulated the hypothesis that a hierarchy of lower and higher order habits was involved in the form of the receiving curve for telegraphy, they decided to test this out experimentally. The habits they had in mind, from lower to higher, were the letter, word, and connected discourse habits. They, therefore, obtained from one subject separate curves for receiving letters, words, and connected discourse and compared these.[19]

[17] E. L. Thorndike, The Psychology of Learning, Columbia University, N. Y., 1913, pp. 279.

[18] C. L. Kjerstad, An unpublished study on the curves for typewriting, p. 85.

[19] Bryan & Harter, Psych. Rev. 1899, Vol. 6, p. 350.

With the exception of one or two studies, no attempts have been made to follow up the method suggested by these early investigators. Thorndike has suggested that it should be possible "to show, if sufficiently ingenious experiments could be devised, just why certain bonds,....., do result in a certain practice curve."[20] Bair's study of the practice curve may be considered an effort in this direction. He varied the same general practice by introducing slight variations such that he procured simultaneously four different results from the same subject.[21] The latest and only real attempt, besides that of Bryan & Harter, to separate a complex problem of learning into its principal factors is a study by Batson.[22] This study was designed particularly for studying the plateaus in learning curves but the results are of general significance in relation to the form of the curve as a whole. Making use of Swift's ball tossing type of learning, he devised means of successfully separating out three factors in this learning for each of which he obtained separate curves. His experiment includes a study of the effect of a number of factors working simultaneously, the effect of an isolated factor, and the effect of several factors working in succession.

An unpublished study of typewriting curves made some time ago and to which we have referred above deserves mention here.[23] In that study, we used four subjects who had not before touched the typewriter. Each of these subjects practiced for one half hour per day for a period of about three months. Two kinds of practice were carried on. Each subject practiced for ten minutes on a practice sentence and followed this with a practice in taking copy for twenty minutes. Thus two practice curves were obtained from each subject. In a comparison of these curves, one outstanding fact was the lack of correlation between the two curves of each individual subject, and opposed to this the very

[20] E. L. Thorndike, The Psychology of Learning, Columbia University, N. Y., 1913, p. 280.

[21] J. H. Bair, Psych. Rev., Mon. Sup. 1902, No. 19, p. 28.

[22] W. H. Batson, Psych. Rev., Mon. Sup. 1916, Vol. 21, No. 91.

[23] C. L. Kjerstad, 1916, An experimental study of the form and fluctuations of the learning curves for typewriting (Unpublished), University of Chicago Library.

striking correlation between the practice sentence curves for the four subjects and also the striking correlation between the copy curves of the four subjects. These results were suggestive in that they indicated the possibility of changing the form of the curve by introducing various external factors.

These attempts suggest that the effect of various factors ultimately may be worked out by so altering the experiments or the problems that factors present in the formation of one curve are not found in another. It is clear that here is an open field for a great deal of work which as yet has only been initiated. It is this possibility of experimentally altering the factors involved which has led to the present study.

We found it necessary, however, to limit our problem to one particular type of learning or learning curve. The survey of the studies made on learning curves indicates that the majority of these have involved some form of motor skill. A number of studies have also been made, to determine the effect of practice upon memory, the results of which have been represented by curves. In all of these investigations the main purpose has been to study the improvement that could be made in the time or in the number of repetitions required for memorizing certain groups of material.

On the other hand, no attempt seems to have been made to find out under varying conditions what relative amounts of a certain group of material will be reproduced after each particular repetition or at different stages during the learning until the group as a whole has been reproduced. The present investigation, therefore, is limited to experimentally test out some of the factors which may be involved in determining the form of memory curves or the learning curves for memory. In other words it is an attempt to determine whether or not, by changing certain factors or conditions in a certain group of material, variations may be produced in the percentages mastered at various stages in the learning. To illustrate: Suppose the percentages mastered at six equal intervals in the process of learning should be in order from first to last, 30, 25, 20, 10, 10, and 5. Could this order be changed by varying certain factors such that the per-

centages would be 10, 20, 30, 25, 10, and 5 or some other order. Only a few of the possible factors, which might be concerned in the form of these curves, could be included in this particular study. The following list is not exhaustive but is suggestive of the large number of possible factors that may effect the form of a learning curve for memory; viz. practice, individual subjects, number of repetitions, kinds of material, length of material, warming-up, fatigue, time of presentation, time for reproduction, method of presentation, method of reproduction, method of measuring progress, interest, attention, effort, inhibition, and the distribution of effort.

Statement of the problem.—This study concerns itself more directly with the form of the learning curves for memory. The purpose is to determine, whether or not, under varying conditions a definite per cent of a definite group of material invariably will be reproduced at certain definite intervals or stages during the progress of the memorizing or learning. In other words, it is an attempt to find out what changes, if any, may be produced in the form of the learning curves by experimentally varying certain factors that may be involved.

Since it would be next to impossible to extend this particular study over all possible factors the following have been selected for the present investigation: viz., to study the effect of (1) practice, (2) individual differences, (3) changes in the kind of material, (4) changes in the length of material, (5) changes in the time of presentation, and (6) certain momentary subjective factors which we have called warming-up and ennui but which may involve interest, attention, effort, and other factors.

Incidentally the number of repetitions required for mastering various lengths and kinds of material has received considerable attention in our results and discussions, due to the fact that our results did not agree with those of some of the best known studies of this phase of the problem.

The Apparatus.—All the material learned by the subjects in this experiment was presented visually by means of a "memory exposure apparatus". This was the ordinary drum apparatus used at the Chicago Laboratory, slightly modified to serve our

specific purpose. This apparatus consisted of a revolving drum which was placed horizontally between two standards or supports about eight inches long fastened to a base about eight by fifteen inches. Upon this drum could be attached the sheets of white manilla board upon which the syllables or other materials to be learned were typed. In front of the drum was an aluminum screen with a long aperture about one half an inch in width which could be closed as much as desired by means of shutters from either side. The whole apparatus was placed upon an ordinary study table when in use. The drum was revolved by hand, the operator timing the exposures of the syllables or pairs of syllables presented. At the suggestion of Dr. Carr, an attempt was made to attach a motor to the apparatus. The complicated timing mechanism necessary made this somewhat difficult, so that it was not perfected until several months after the experiment was well under way and it was decided to complete the experiment with the hand apparatus rather than to complicate matters by using the motor apparatus for a part of the experimental work.

Materials.—Five kinds of memory materials were used in the experiment: the paired nonsense syllable material, the paired noun meaning material, the serial nonsense syllable material, the paired number-syllable material, and the paired consonant-syllable material.

The Paired Nonsense Material & The Serial Nonsense Material: The nonsense syllables were constructed by making combinations of two consonants and a middle vowel. The actual number of syllables of this kind that can be made from five vowels and twenty-one consonants is 2289. Discarding those in which the first and the last consonants are the same there remains 2268. From these were discarded those which formed meaning words and those which could not be pronounced as syllables. This left 1228 syllables for actual use. In the experiments, the series were so arranged that a subject was always given an entirely new set of syllables. No syllable was used more than once in any connection for the same subject. From these syllables, selected at random, the paired nonsense material, consisting of series of various lengths of pairs of syllables, was

made up; likewise the serial syllable material consisting of single columns of nonsense syllables of various lengths.

The Paired Meaning Material: This consisted of paired monosyllabic nouns. 1747 of these nouns were picked from Webster's Unabridged Dictionary and, like the nonsense syllables, written on little cardboard tickets which were mixed in a box from which they were selected at random. Only nouns were used in order that the material might be more uniform. It is, of course, clear that uniformity of a group of nouns can only be relative, depending upon the individual subject almost as much as upon the material. Monosyllabic nouns were used in order that they might correspond to the nonsense material in all respects except that of meaning.

The Paired Number-syllable Material: This consisted of three place numbers paired with nonsense syllables. Three place numbers were used to correspond to the three elements of the nonsense syllables. Six hundred forty seven such numbers were prepared and selected at random for use in the series.

The Consonant-syllable Material: This material was made to correspond to the number-syllable material. Three place consonant syllables were used in place of three place numbers. Only a very small amount of this material was prepared and used.

Experimental Procedure

For the Paired Nonsense Material: In the experiments in which this material was used, the syllables were arranged in pairs and typewritten on the sheets of soft white manilla board. Where the two syllables together made sense one of them was discarded. The series made up from the first syllables of each of these pairs may be called the test series and the other the associate series. Following the paired series on the same manilla board sheet the test series was written again, so that it could be turned to immediately after the paired series had been exposed. However, the order of the test series in the new position was changed so that the subject could not recall the pairs by reason of the temporal order.

The changed order of the test series was made according to an

arbitrary rule but this is so complicated that it would not be worth while to state it here. In place of it, we give in the following illustrations the order in the various lengths of materials used in our experiments. The figures in the first line represent the original order while those in the second line represent the same syllables as they appeared in the new order.

Twelve Pairs

Original Order	=	1	2	3	4	5	6	7	8	9	10	11	12
New Order	=	7	9	4	8	10	5	12	3	1	11	2	6

Eighteen Pairs

Original Order	=	1	2	3	4	5	6	7	8	9	10	11	12	13	14
New Order	=	10	12	14	16	18	1	13	5	17	7	15	3	11	8
		15	16	17	18										
		6	14	2	9										

Twenty-Four Pairs

Original Order	=	1	2	3	4	5	6	7	8	9	10	11	12	13	14
New Order	=	13	15	4	19	8	23	1	16	5	20	9	24	11	22
		15	16	17	18	19	20	21	22	23	24				
		7	18	3	14	10	21	6	17	2	12				

Thirty-Six Pairs

Original Order	=	1	2	3	4	5	6	7	8	9	10	11	12	13	14
New Order	=	19	21	4	25	8	29	12	33	16	20	3	24	7	28
		15	16	17	18	19	20	21	22	23	24	25	26	27	28
		11	32	15	36	17	34	13	30	9	26	5	22	1	35
		29	30	31	32	33	34	35	36						
		14	31	10	27	6	23	2	18						

It is evident that this scheme of rearrangement was rather complicated but it seemed to serve the purpose of successfully keeping the subjects from guessing where to look for any particular test syllable. The purpose was to make the subject depend upon the association between the two members of each pair without attempting any connection with members of other pairs in the series.

Definite instructions were given to the subject at the first sitting. The subject was seated facing the aperture in the screen and told that twelve, or whatever the number of pairs of syllables happened to be, would be successively brought to view in the aperture one at a time. "Each syllable consists of a middle vowel and two consonants. Each of these pairs will be exposed for a period of three seconds. As each pair comes to view you may vocalize it in a whisper if you wish, but always keep your eye and attention on the pair in the aperture even though you are positive that you already have learned it. You should try to

associate the two syllables such that when later the first one is presented you can reproduce the second. In doing this you are free to use meaning or any other method you may hit upon. These pairs must not be thought of during the presentation except when they are visually before you. As soon as one pair drops from view and the next one is presented place your whole attention at once upon the new pair. As soon as all the pairs have been exposed the test series will be given. This series consists of the first members of each pair; these are, however, presented in a different order from that in the first exposure. As each of these are presented, five seconds will be given for reproducing the missing associate. If the associate or a part of it comes to mind write it on the paper provided. If in your judgement no syllable that you can think of is the correct associate, indicate this with a dash. Three minutes intermission will be given between the attempted reproduction and the next re-exposure of the series. During this time you should keep your mind off the series all together. The presentations will be continued until you can correctly reproduce all the associate syllables."

These instructions were always made clear to the subject before any presentation was attempted. Parts of the instructions were repeated each day until we were sure that the subject followed them as carefully as he could.

The same instructions were given and the same procedure followed in the paired meaning, the number-syllable and the consonant-syllable material, as in the paired nonsense syllables, except that the difference in the material was made plain to the subject.

For the Serial Nonsense Syllables: In the use of this material the instructions and procedure had to be somewhat different. The subject was told that these were series of single syllables. These syllables would be presented one at a time for three seconds, but he was permitted to spread his attention to any syllable or group of syllables during the presentation. When all the syllables in the series had been presented the subject was asked to reproduce in writing as many as he could, giving them

in the order presented if possible. After this the series was presented again. The presentations were continued until all the syllables were correctly reproduced in the order given. In these series it was not possible to limit the subject's time for reproduction. They were, therefore, permitted to take their own time but with the knowledge that they were being timed. While in the paired series the time given for reproduction was five seconds for each syllable, the average time taken for the serial syllables ranged from three to ten seconds. It was quite uniform for each subject and each kind of material.

In General

In all the experiments from five to six sittings per week were given as regularly as possible and at the same hour of the day for each subject. Exceptions to this, unfortunately, did occur at times; since it is impossible to impose upon human subjects any absolute routine. This, unfortunately, is one of the difficulties for the experimenter who undertakes to work with human subjects. As far as our results are concerned, however, the irregularities were not serious; in fact we doubt if any differences in the results did occur.

Subjects.—Subjects A, B, D, E, F, G, H, I, K, and R were all graduate students working in psychology. All of these were men except subject E. Subject C was a graduate student in history, and subjects L, M, N, O, P, Q, J, S, T, and U were primary teachers and normal school students. With the exception of C, J, and T these subjects were women.

Data.—In this study the nature of the problem made us depend upon the objective data as given by the subjects. The subject had to give his whole attention to the task before him without attempting any introspective observations as to what was taking place during the progress of each day's experiment. Certain introspective data were, however, incidentally obtained at the end of each sitting which in some cases aided in the interpretation of the results obtained. These were as a rule entered with the typewritten copy of the objective data from each subject for each sitting. The data consisted of a copy of the material to be

learned, the name of the subject, the date and the hour of the experiment, the number of repetitions required for complete reproduction with the actual material reproduced by the subject in each attempt. Where the time was not otherwise controlled by the experiment this was entered for each attempted reproduction.

II. METHODS OF SCORING, COMPARING, AND PRESENTING RESULTS

Sec. 1. A New Method for Scoring Materials Learned

In dealing with the materials or results from our subjects, one of our first difficulties was that of assigning values to the material reproduced. Where the subjects reproduced words, syllables, or numbers correctly the scoring was simple, but where only parts of these were reproduced it was much more difficult. Other elements, such as position of syllables and position of letters and figures, made the problem still more complex and difficult.

Numerous experiments have been conducted using materials somewhat similar to those used in our experiment but very few attempts have been made to arrive at a scientific scoring of these materials and their elements. It is possible that the arbitrary means of scoring served the purpose just as well for their particular problems. In our problem, where we were constantly considering amount of material mastered at progressive intervals in the learning a correct method of scoring became very important, in fact, absolutely essential.

The only article in the literature dealing exclusively with this question is one by D. O. Lyon entitled; A Rapid and Accurate Method of Scoring Nonsense Syllables and Words.[1]

Unfortunately this method, like all other methods with which we are acquainted, is nothing more than an arbitrary assignment of values. The following quotation will serve as a brief statement of the method as it concerns nonsense syllables: "Briefly stated, the method for nonsense syllables was as follows: Each correct letter provided the syllable was in the correct position received a score of one, and the syllable received an extra score of one for being in the correct position. Thus a perfect syllable received a mark of four while a syllable correct in itself but not correct in position received a score of only three. If two of the

[1] D. O. Lyon, Amer. Jour. of Psych., 1913, Vol. 24, pp. 525-531.

three letters of the syllable were correct but the position of the syllable itself were not correct, it was not scored at all. Therefore unless the position is correct the separate letters do not count at all unless all are correct."

The rapidity of this method can not be doubted but its accuracy may well be questioned. No reason is given for assigning these values to the different parts or elements of the syllable. They seem to have been assigned for no other reason than ease and convenience. One might be justified in concluding that because a method is simple and easy, presto it is rapid; but hardly, presto it is accurate. Is there any reason why the same value should be given to the position of a syllable as to one of its letters? If we assume that the mastery of the position of a syllable presents the same difficulty to the mind as the mastery of a letter, yes. Again, is there any reason why the same value should be assigned to the first consonant as to the vowel, or to the vowel as to the second consonant? If we assume that each of the three letters of the syllable presents equal difficulty to the mind, yes. Thus if we are correct in assuming that the mastery of each of these four elements presents equal difficulty to the mind, then the method used by Lyon might be accepted as accurate provided again that these are the only elements involved. However, Lyon, himself, finds that there is one element not comprised within his original scheme, i.e., the position of the letter in the syllable. He finds cases in which the consonants of the syllable are reversed in their position and to this syllable, if correct in every other respect he assigns a value of two. This means that if the consonants of a syllable are reversed, he assumes that the syllable is only half learned or mastered. In other words it is as difficult for the mind to master the position of these two consonants as all the other elements combined. How can the value of two be assigned to the position of these consonants when each element plus the position in his original scheme is given a value of only two and the whole syllable a value of four?

From the point of view of mere chance the assigning of the same value to the vowel as to the consonant seems a very questionable procedure. Since there are only five vowels the chances

are that this element of the syllable will be correct one out of five times on a mere guess, while for the consonant it will be correct in only one out of twenty-one times. Were we to score the elements of the syllable on this basis we should have to give the vowel a far lesser value than the consonants. We are, however, not dealing with mere chance but rather with inborn and acquired habits of mind which do not necessarily follow any such simple mathematical formula.

Some other basis must be found upon which to fix the relative values of the different elements in the syllable. This basis, we think, can be found in the relative difficulty encountered by the mind in their mastery. If we should find that the mastery of the position of the syllable presents the same difficulty to the mind as the mastery of each of the letters then we should have reason to assign to it the same value. If it be found equally difficult for the mind to master or reproduce each of these various elements then the method used by Lyon might be correct. If, however, it be found, for instance, that the first consonant presents greater difficulty than the last, the last consonant than the vowel, and the vowel than the syllable position, then his evaluation can not be accepted as accurate. Suppose a man were given the task of climbing four poles, one with spiked steps, one rough, one smooth, and one smooth and greased; he would not be rash enough to say that when he had climbed the spiked pole he had mastered one fourth of the task. The task cannot be measured merely in terms of the number of elements involved; their relative difficulty must be taken into consideration.

But how are we to arrive at so vague a thing as the relative difficulty to the mind of each element of a syllable? This might at first thought be considered next to impossible. We believe, however, that the basis for the measure of such difficulty may be found in a study of the errors made due to each of the elements involved. If we should find that the cause of the syllable being wrong is due in one half of the cases to the interchange of the consonants and the other half of the cases to one or more other elements then the difficulty of mastering the position of the consonants would have to be equal to that of mastering the other ele-

ments. If this were true Lyon's scoring of the position of the consonants would be correct. Again if we should find that the cause of the syllable being wrong is due to the incorrect vowel in ¼ of the cases, to the incorrect first consonant in ¼ of the cases, to the incorrect last consonant in ¼ of the cases, and to the incorrect position of the syllable in ¼ of the cases, then it would seem that these four elements represent equal difficulties and each of these should be given the same value in the scoring of the parts of the syllable. If these were the facts in the case, then we could accept the values given by Lyon to the letters and the position of the syllable as accurate.

With these possibilities before us we are prepared to inquire into our own results. We will take up first of all the paired nonsense material more or less in detail after which we will study the other kinds of material in relation to this.

The following table (Table I), was obtained from the results of 126 series of twelve pairs each, representing results from nine different subjects. The column marked S represents the number of series for each subject; V the number of times the syllable is wrong, due to errors in the vowel, 1C to the errors in the first consonant, 2C to errors in the last consonant, and P to the errors in the syllable position. The error in each case was either an omission or a substitute for the correct element. The interchange of the first with the last consonant occurred once or twice for most of the subjects but these were not numerous enough to be taken into consideration.

TABLE I

The Number of Each Kind of Error for Individual Subjects

Subject	S	V	1C	2C	P
A	26	30	54	86	96
B	26	15	46	99	39
C	20	31	59	78	41
D	12	3	14	32	12
E	6	5	7	11	8
F	6	9	13	27	12
G	6	13	13	30	6
H	8	12	23	14	13
I	16	33	43	81	13
Totals	126	151	272	458	240

Comparisons, of the number of errors due to the various elements and for the different subjects, present some very interest-

ing facts. It should be remembered that the possible number of errors is the same for each of the elements, excepting the vowel, for each subject, when measured in terms of chance. In spite of variations for each element and subject, the table presents considerable uniformity in several respects. Taking the three letters of the syllable, we find that in every case the vowel is the cause of the least number of errors, the first consonant comes next for all subjects except H, and the last consonant is the greatest offender of all for all subjects except H. Whether with an increase of the number of cases H would have tended to conform to the group we can not tell. The difference may be due to a peculiarity in the method of learning. The relative number of times that the syllable is wrong due to error in position is not so uniform, yet it is sufficiently so to be noticeable. For five of the subjects the number comes between that of the vowel and the first consonant, for two subjects it falls below that of the vowel, for one between the vowel and the last consonant, and for one above that of the last consonant. The total for all subjects naturally falls between the first consonant and the vowel.

From the totals of all cases the number of errors from less to greater arrange themselves in the following order: vowel, syllable position, first consonant, and last consonant.

It occurred to us that the order might possibly change with practice. The fact, that the order for the subjects who had twenty-six series is the same as that for those who had only six, is, however, in itself evidence that the order is a constant. In order to test this hypothesis further we constructed the following table (Table 2), from the errors of the three subjects who had twenty or more series. The table gives the number of errors for each element for the first half and the last half of each subject's work.

TABLE 2

Number of Errors for the First Half and the Second Half of Each Subject's Practice

Subject		V	1C	2C	P
A	1st Half	25	35	52	65
A	2nd Half	5	19	35	32
B	1st Half	5	26	51	22
B	2nd Half	10	20	48	17
C	1st Half	20	35	44	25
C	2nd Half	11	24	34	16

The table shows that there is some variation in the number of errors in each case yet the relative position for each element is the same for each half as it was in the first table.

In the following table, (Table 3), the totals from the 126 series of the twelve paired series is compared with the total errors due to each element from longer paired syllable series. (Series were 24, 18, and 36 pairs in length, given to six different subjects.) The errors due to each element still hold the same relative position as to numbers as in the twelve paired series.

TABLE 3
Relative Number of Errors for Materials of Various Lengths

	S	V	1C	2C	P
12 syllable series.....	126	151	272	458	240
18, 24, and 36 syllable series.....	26	72	102	141	64
Totals.....	152	223	374	599	304

From our results thus far, it appears that we almost invariably get the same order, i.e., V, P, 1C, and 2C, for all the paired nonsense series. If we remember that the possibility of errors is the same for all elements, i.e., there are an equal number of vowels, consonants, and positions concerned, then we may conclude from the above results that in the case of the paired nonsense material learned as in our method of procedure, the mind finds least difficulty in reproducing the vowel element, greater difficulty in reproducing the syllable position, still greater difficulty in reproducing the first consonant, and the greatest difficulty in reproducing or mastering the last consonant of the syllable. The results indicate further, that, although the advantage is with the vowel, it is not nearly so great as one might suppose from the chance advantage it would have in a mere guess compared with the consonants. Again we find that if we add the number of errors due to the vowel and first consonant we get a sum of 597 as compared with 599 for the last consonant. That is, the last consonant is the cause of error as often as the vowel and the first consonant combined.

In the following table, (Table 4), are given the totals in errors due to the various elements of different kinds of materials. A represents the paired nonsense already discussed; B the serial

nonsense material; C the numbers paired with nonsense syllables; D consonants paired with nonsense syllables; and E the serial consonant material. S represents the number of series or cases; V represents the number of errors due to the vowel, middle figure, or the middle consonant; 1C those due to the first consonant or figure; 2C those due to the last consonant or figure; P those due to the syllable position; EP those due to the element position; and Av. the average number of errors for each series.

TABLE 4
Total Number of Errors for Different Kinds of Material

	S	V	1C	2C	P	EP	AV.
A =	152	223	384	599	304	—	9.89
B =	180	294	284	604	447	—	9.05
C =	66	138	85	160	293	176	13.00
D =	6	8	2	20	76	14	20.00
E =	6	4	4	5	70	3	14.17

Even though it may involve repetition, a word is in place here with reference to the kinds of material from which the above data were taken as well as the method of learning and reproduction in each case.

Series A, C, and D were alike in that they contained one set of association syllables or a cue series. In A these were paired with another series of nonsense syllables, in C with numbers of three figures each, and in D with syllables of three consonants each. In learning, these were presented one pair at a time and the subject was required to keep his attention upon each pair only so long as it was visually before him or until the next pair was presented. He tried to fix the members of each pair in his mind so that when later the cue syllable was presented he could reproduce its associate. Series B were series of serial nonsense syllables and series E three place consonant series. These were presented one at a time visually and the subject was left free to distribute his attention over the series as he saw fit and could series no cue was given except as each syllable reproduced by the subject might be a cue to the one following.

The Serial Series B: Series A have been discussed in detail above. The table, (Table 4), shows that the average number of

errors for the B series is almost identical with that of the A series. The relative number for each element is, however, slightly different. The order from less to greater is: first consonant, vowel, syllable position, and last consonant. The last consonant is again the greatest offender, while the vowel and the first consonant are almost on a par. As in series A, we find that if we add the number of errors due to the vowel and first consonant we get a sum which is no larger than the number due to the last consonant alone. Just why there should be relatively less errors due to the first consonant in the unpaired series, we are not prepared to say. No doubt the method of learning and the method of reproduction are responsible for the change. Possibly certain motor and kinaesthetic factors involved in the B series may give rise to greater emphasis upon the first consonant and thus lessen the relative proportion of errors for it.

Series C, D, and E. (Numbers and Consonants). In these series the loss of the vowel element gives rise to certain changes. In the first place the average number of errors is increased. A new factor, the position of the element, figure or consonant, enters. The figures or consonants are often interchanged or placed in the wrong position. The first consonant or figure now takes the place of the vowel in that it gives rise to far less errors than any other element. In these series the order is: first figure, second figure, third figure, element position, and syllable position. In the D series the element position comes before the last figure and in the E series it comes before the second figure which corresponds to the vowel.

Summary

1. Errors in the reproduction of nonsense syllables may be due to any one of four elements: the vowel, the first consonant, the last consonant, or the syllable position.

2. The vowel in a nonsense syllable is relatively the cause of less errors than any other element, yet it is relatively the cause of more errors than would result from mere chance or guess.

3. The last consonant of the syllable is relatively the cause of

more errors than any other element and is the cause of as many errors as the vowel and the first consonant combined.

4. The average number of errors for each series of nonsense syllables reproduced remains much the same whether controlled cue associations are used or the serial syllables in which the subject is given more freedom both in learning and reproduction.

5. Where the three elements of the syllable are identical in kind, as figures or consonants, a new factor the element position enters as a cause of error.

6. The order from less to greater in the cause of error is as follows in the various kinds of material:

	1	2	3	4	5
Paired Nonsense Syllables = - -	V	P	1C	2C	—
Serial Nonsense Syllables = - -	1C or	V	P	2C	—
Paired Nonsense Syllables & Numbers =	IC	V	2C	EP	P
Paired Nonsense Syllables & Consonant Syllables =	1C	V	EP	2C	P
Serial Consonant Syllables = - -	EP	1C	V	2C	P

7. The most significant result from this whole study is the invariable fact that where the *three* elements of the syllable, be it numbers or consonants, are of the same kind the order in the cause of error from less to greater is always from first to last or from left to right. Our results show quite conclusively that the human mind, be it from innate nature or from training or both, grasps and reproduces most easily the first or left hand element and with greatest difficulty the last or right hand element of a syllable or a number of three figures. This is in part contrary to the well known fact that in memorizing a group of syllables or other material the first and last parts are mastered before the parts in between. Our results thus tend to show that in the learning of nonsense syllables or numbers the same law does not hold true for parts or elements of the individual syllable or number. Here the first part is learned first and the last part last as measured in terms of the number of errors.

8. The results from our study, it appears, show that it is possible to make the errors a basis for scoring of the various parts or elements of a syllable or number. The facts produced support our theory that the errors are a function of the difficulty of the various elements in the syllable or number. The relative diffi-

culty encountered by the mind in mastering each of these elements may thus be measured in terms of the relative number of errors caused by each element and thus be made to represent the relative value or score of each part or element.

It is evident that the values will apply only to the specific kinds of material for which they are worked out. The principle, however, is applicable to nearly all kinds of material; such as parts of geometric figures and runways and alleys of the maze. Our results show, however, that the scores given to the elements by the method used by Lyon are not accurate. The relative values, according to our results can not be identical for the different elements.

Values Used in Scoring.—We found that in the case of the paired nonsense series the syllable elements are the cause of error in the following order from less to greater: V, P, 1C, 2C. This means that the vowel is the least difficult to master and should consequently be given the least value, then in order of value should come the syllable position, the first consonant, and finally the last consonant which should be given the greatest value. In the case of the serial syllables the order of value should be, from less to greater: first consonant, vowel, syllable position, and last consonant. For the numbers it should be: first figure, second figure, third figure, element position, and syllable position.

Using the total of errors due to each element as a basis, the per cent of error can be determined and this will then be a measure of the relative difficulty of each element and may thus be made to represent its relative value.

The following tables show the relative number of errors, E; the relative percent of error, %; and the relative value, RV; which were assigned and used in our scoring.

TABLE 5

Paired Nonsense Syllables

	E	%	RV
V =	223	14.8	3
1C =	384	25.4	5
2C =	599	39.7	8
P =	304	20.1	4

TABLE 6

Serial Nonsense Syllables

	E	%	RV
	294	18.1	2
	284	17.4	2
	604	37.1	4
	447	27.4	3

TABLE 7
Numbers Paired with Syllables

	E	%	RV
Fig. 1 =	85	10.0	1.0
Fig. 2 =	138	16.2	1.5
Fig. 3 =	160	18.7	2.0
P =	293	34.5	3.5
EP =	173	20.6	2.0

TABLE 8
Consonant Syllables

E	%	RV
5	3.0	1.0
12	7.0	2.5
25	15.0	5.0
111	65.0	21.5
17	10.0	3.5

TABLE 9
Paired Meaning Material

	E	%	RV
Position	= 35	40.0	2
Substitution	= 53	60.0	3

The relative values worked out for the consonant syllables are based on too few cases, i.e., only twelve, to be entirely satisfactory. The high relative value for the syllable position may be questioned; yet there is no doubt but that it should be higher than in the case of the other materials. The mind naturally would find it more difficult to associate three consonants with a syllable, since they lack entirely the unity possible for three figures or two consonants and a middle vowel.

In the case of the meaning material, where words are learned as unit wholes, we did not expect to find any other errors but those of position. Upon careful study of the material two kinds of errors were found. One was that of position, P; the other was that of substitution, S. This last error, as may be seen from Table 9, was the most common. This error consisted in substituting for the correct word a word similar either in meaning or in sound. The table shows the total number of errors of each kind found in the results from our subjects with a total of 58 series of cases. It is clear from the table that the errors in this material were extremely few as compared with those of other materials. In most cases the subject either reproduced the correct word or else he failed to give anything.

In our scoring we have based our relative values upon the actual number of errors produced by each element considered and neglected other possible factors. Our purpose has been to get a valuation that would not involve too complicated a procedure and yet be accurate enough for practical purposes. We have at least arrived at a valuation more accurate than any based upon mere guess or upon pure chance possibilities. It is clear

that the method of scoring syllables and parts of syllables will modify the results in no small degree, especially where the number of errors is large.

We have used in this thesis the scores which we have given above. They represent the values of syllables and elements of our material as nearly as they can be derived on a scientific basis.

Sec. 2. Methods of Grouping, Comparing, and Presenting Results

Another difficulty which presented itself was that of grouping, comparing, and presenting the results of our experiments in some intelligible fashion.

As already indicated, several curves were obtained from each subject. Some of these were the result of twenty-five or more trials or repetitions; while others, especially after practice, required only six or even less repetitions for learning the material given. Obviously we could not do as has been done in some experiments on animals in which the same number of trials were given to each animal. We had to limit the number of presentations to those required for the first accurate reproduction of the material whether it took five or thirty repetitions.

Dr. Vincent, in connection with experiments on white rats, calls attention to the unfairness of giving the same number of trials to all animals, no matter whether they master the problem in few or many trials.[2] She points out that a problem is learned "when it can be performed relatively free from error whether it takes ten or forty trials." She, therefore, adopted a method as follows: "In this experimental work an animal's trials were discontinued when the problem was learned or one period beyond such time. The numerical results of time and error for each animal were then divided into an equal number of serial groups, say ten, regardless of whether in the learning he had taken twenty of forty trials. In the one case there would be two numbers in each group and in the other four. The averages were then taken by groups and thus there was obtained for each animal a series of ten numbers. If there was an excess it was always distributed among the beginning group." In other words, Dr. Vincent

[2] Vincent, E. B., Behavior Monographs, 1912, Serial No. 5, pp. 16, 17.

grouped trials by twos, threes, or fours as the case might be. The averages of these were taken and thus a group curve obtained.

This procedure is a decided improvement in method and might be accurate enough for some problems and for work on animals. Our problem and purpose was, however, somewhat different. In our results the excess or odd numbered trials or repetitions would not be sufficiently distributed by this method. Furthermore, we wanted to compare, not only different curves, but different stages of learning in the same curve. For this reason the following method was devised: Every individual curve was accurately drawn on cross section paper provided for this purpose. This curve accurately represents the progress of the subject until complete reproduction resulted. Having the curve, it is possible to select any point on it and get the percentage reproduced at that point. All one needs to do is to take any point on the base line and follow the vertical line from this point to the point where it intersects the curve. The distance of this point from the base line indicates the percentage reproduced at this stage of the learning. It is thus possible to tell in a moment how much of the problem the subject has mastered in halves, thirds, sixths, tenths, or any other number of divisions one might wish to make.

The advantage of this method for our purpose over that used by Dr. Vincent is two fold. First, it takes care of the odd number of repetitions which by her method were distributed among the first groups. By our method, every trial gets its full value. Second, it permits us in a moment, without calculation, to find the percentage or the part of the problem mastered at any particular stage in the learning.

As has been mentioned before, several curves were derived from each subject for each kind of material. The results given in the following studies are always averages from the individual curves of each subject. The number of curves from which the averages were taken is stated in all our tabulations and ranges from six to twenty-six curves.

The reader may be disappointed in not finding a large number of graphical learning curves on the following pages. In a treatise of this kind, we found it impracticable to use the usual method

of graphical representation of the results. This for two reasons: First, on account of their number, it would have required pages and pages of these curves in order to represent the results for each particular study made. It is clear that these would not have been of much value for comparative purposes. The second and most pertinent reason for not using the usual graphical forms of the curves is that, as will be shown later, the curves were found to be so much alike that the graphical method would not at all indicate the differences where they were found.

In place of the graphical representations, we have, therefore, made use of numerical tables. These we found would bring the results into a more compact form for comparison and, furthermore, would show even the slightest variation in the curves. We were interested to know at what points in the curve the learning was most rapid and at what points it was least rapid. To arrive at this, we found the following procedure the most advantageous and it has been followed throughout all our studies.

Tables were made from the curves giving the percentages reproduced in successive halves, thirds, and sixths. These various points on the curves were thus represented in figures and in this way comparison of the various curves are possible by comparing these particular points in the learning. Likewise, it is possible to get averages of these points and thus get averages from a group of curves which are comparable in the same way. It would, of course, have been possible to take still other points in the curves than those taken but the comparisons would have been made more difficult and the value of the additional details would have been slight.

For general purposes, this method should also be of value. These figures can be compared with those from halves, thirds, and sixths of any other curves and of any kind of problem from which they may be derived.

The tables will be described in greater detail in connection with each of the studies made. Besides the percentages reproduced in halves, thirds, and sixths there will be found in each table the number, or in some cases the average number, of repetitions required for complete and accurate reproduction; as well as the number of cases from which the averages were taken.

III. EXPERIMENTAL RESULTS

Sec. 1. Practice Effect. The Effect of Practice Upon the Form of Learning Curves for Memory.

It is a truism among those who have performed experiments on memory that some improvement does occur from practice in memorizing specific kinds of material, in the sense that one can memorize more quickly or with fewer repetitions and with less effort. This fact is due, no doubt, as suggested by James, to improvement in method and "elaboration of associations" for specific kinds of materials rather than to a general improvement of native memory as such.

Our problem here, however, was to determine whether there might not at the same time be some change in the learning curve for memory due to practice. In other words we wished to see whether or not the relative amounts of a certain group of material mastered at different intervals during the learning of that group or rather similar groups, would remain the same after practice. For this purpose we procured, through methods already described, 261 curves from seventeen subjects and for four kinds of material. The curves for each specific material were tabulated separately for comparison.

As would be expected, the individual curves present considerable variation. This, connected with the fact that so many curves could not well be brought together in their original form and compared in any practical way, made it necessary to resort to some other method that would present the main facts in some intelligible fashion. Two methods were adopted to show changes that might occur in the curves: first, by comparing, by means of our general method of tabulation described above, averages of the curves for the first half of the practice periods with averages of the curves for the second half for each kind of material; second, by representing graphically in detail specific points in each of the memory curves from the first to the last in order.

For the paired nonsense material, we used the results of sub-

jects A, B, C, D, E, and F representing 26, 26, 20, 16, 12, and 8 practice periods respectively and a total of 108 curves. (A practice period signifies the time and number of presentations required to learn and reproduce accurately a certain group of material resulting in a memory curve.) For the serial nonsense material, we used the results from subjects L, M, P, Q, and R representing 24, 24, 10, 9, and 12 practice periods respectively or a total of 79 curves. For the meaning material, we used the results from subjects G, H, and I representing 20, 20, and 10 practice periods respectively and a total of 50 curves. For the numbers paired with nonsense syllables, we used the results from subjects N, O, and M representing 8, 8, and 8 practice periods respectively and a total of 24 curves.

A. *Tabulations and Comparisons by Halves of Total Practices*

In making comparisons of averages, we have made tabulations showing the average percentages reproduced by halves, thirds, and sixths of the effort expended for the first half and the last half of the practice periods or curves of each individual subject. Following the tables for the individual subjects for each kind of material, we have a table showing the averages of all the curves for all the subjects for the first half and the last half of their practice periods. Finally we have a table indicating the number of subjects showing an increase and the number of subjects showing a decrease in the averages for the last half of the practice periods.

We can make clear the tabulations, (Tables 10-13), for each subject by taking those of subject A, Table 10, as an illustration. The horizontal row of numbers preceded by A I represents the averages of the first thirteen practice periods or curves of this subject and that preceded by AII the averages for the last thirteen practice periods or curves. The column marked P represents the average number of presentations required for each of the curves, 7.6 for the first half or thirteen and 6.6 for the last half or thirteen curves. In the first column marked 1 the 63.8 represents the average percent ~~reproduced~~ added during the first half of the effort expended for the first thirteen curves and 63.6 the

average percent for the last thirteen curves. In the first column marked 2 the 34.2 represents the average percent ~~reproduced~~ added during the second half of the effort expended for the first thirteen and 36.4 for the last thirteen practice periods or curves. Likewise in the columns marked 1, 2, and 3, we find the percentages ~~reproduced~~ added in thirds of the effort expended and in columns marked 1, 2, 3, 4, 5, and 6 the percentages ~~reproduced~~ added in successive sixths of the time or effort expended. Thus the results of this subject indicate slight changes in the curve for the last half of the practice periods but with no pronounced changes in its general form. Taking the curves as represented in sixths, we see that the greatest change is found in the second and the third sixths, while there are practically no differences in the first, fourth, fifth, and last sixths. The tables of the other subjects are quite similar to those of subject A.

As the figures stand they represent points in the curve so far above the preceding point and do not indicate the distance from the abscissa or base line. If they were "added" successively, they would represent points as far above the base line as indicated by their sums. To illustrate, subject A for the first half of his practice periods, i.e., A I, by sixths reproduced 22.1 per cent of the material on the average for the first sixth of his effort, 22.1 thus represents a point in the average curve one-sixth of the distance from the ordinate and 22.1 points above the base line. 28.1 represents the average percent reproduced in the second sixth of the effort and represents a point two-sixths or one-third the distance from the ordinate but 22.1 plus 28.1 or 50.2 points above the abscissa.

Averages from the First Half of the Curves Obtained Compared with Averages from the Last Half. Tables 10, 11, 12, and 13.

TABLE 10

Paired Nonsense Material

		Halves		Thirds			Sixths					
Sub.	P	1	2	1	2	3	1	2	3	4	5	6
A I	7.6	65.8	34.2	50.2	30.8	19.0	22.1	28.1	15.6	15.2	8.4	10.6
AII	6.6	63.6	36.4	41.3	38.1	20.6	20.3	21.0	22.3	15.8	9.2	11.4
B I	8.0	69.2	30.8	44.3	33.6	22.1	18.6	25.7	24.9	8.7	9.8	12.3
BII	5.0	66.5	33.5	42.6	39.5	17.9	19.2	23.4	23.9	15.6	7.2	10.7
C I	9.8	55.6	44.4	35.4	39.2	25.4	18.1	17.3	20.2	19.0	13.4	12.0
CII	7.0	55.0	45.0	35.5	42.4	22.1	16.4	19.1	19.5	22.9	12.8	9.3
D I	9.5	53.8	46.2	31.0	44.7	24.3	12.1	18.9	22.8	21.9	13.0	11.3
DII	8.4	57.8	42.2	36.0	39.8	24.2	15.5	20.5	21.8	18.0	11.7	12.5
E I	5.2	59.8	40.2	37.6	36.7	25.7	14.8	22.8	22.2	14.5	18.2	7.5
EII	4.3	57.1	42.9	31.8	46.3	21.9	15.5	16.3	25.3	21.0	13.0	8.9
F I	5.3	52.6	47.4	33.8	38.7	27.5	15.0	18.8	18.8	19.9	11.9	15.6
FII	5.7	56.1	43.9	35.0	41.0	24.0	11.8	23.2	21.1	19.9	12.0	12.0
Averages Curves												
I	54	61.3	38.7	40.6	36.4	23.0	17.8	22.8	20.7	15.7	11.6	11.4
II	54	60.6	39.4	38.2	40.6	21.2	17.4	20.8	22.4	18.2	10.4	10.8
Increase and Decrease												
		1	2	1	2	3	1	2	3	4	5	6
Increase		2	4	3	5	1	3	3	3	4	2	3
Decrease		4	2	3	1	5	3	3	3	2	4	3

Figures in the table of increase and decrease represent the number of subjects showing either an increase or a decrease for the fractional part in the second half.

TABLE 11

		Halves		Thirds			Sixths					
Sub.	P	1	2	1	2	3	1	2	3	4	5	6
L I	9.0	72.2	27.8	53.8	29.8	16.4	35.0	18.8	18.4	11.4	8.3	8.1
LII	5.1	80.9	19.1	58.5	32.5	9.0	34.1	24.4	22.4	10.1	5.0	4.0
M I	5.0	76.1	23.9	54.9	33.6	11.5	32.4	22.5	21.2	12.4	5.8	5.7
MII	5.2	71.1	28.9	53.6	28.0	18.4	28.6	25.0	17.5	10.5	10.4	8.0
P I	6.8	64.7	35.3	52.2	28.6	19.2	31.5	20.7	12.5	16.1	9.9	9.3
PII	3.8	74.5	25.5	58.7	29.7	11.6	34.0	24.7	15.8	13.9	6.6	5.0
Q I	7.0	68.4	31.6	53.0	26.0	21.0	33.6	19.4	15.4	10.6	11.5	9.5
QII	5.4	73.1	26.9	54.6	33.6	11.8	32.7	21.9	18.5	15.1	5.9	5.9
R I	8.7	67.3	32.7	55.4	26.1	18.5	36.3	19.1	11.9	14.2	8.2	10.3
RII	8.2	73.1	26.9	59.8	21.7	18.5	48.0	11.8	13.3	8.4	9.7	8.8
Averages Curves												
I	39	71.2	28.8	54.0	29.9	16.1	33.8	20.2	17.2	12.7	8.1	8.0
II	40	74.9	25.1	56.7	29.3	14.0	34.3	22.4	18.2	11.1	7.6	6.4
Increase and Decrease												
		1	2	1	2	3	1	2	3	4	5	6
Increase		4	1	4	3	2	2	4	4	1	2	1
Decrease		1	4	1	2	3	3	1	1	4	3	4

Figures in above table represent number of subjects for whom increase and decrease occurred in the fractional parts.

TABLE 12
Paired Meaning Material

		Halves		Thirds			Sixths					
Sub.	P	1	2	1	2	3	1	2	3	4	5	6
G I	3.2	67.5	32.5	47.1	38.0	14.9	23.8	23.3	20.4	17.6	7.9	7.0
GII	3.2	65.8	34.2	46.0	37.2	16.8	21.7	24.3	19.8	17.4	9.3	7.5
H I	3.9	71.5	28.5	48.3	38.0	13.7	24.1	24.2	23.2	14.8	7.9	5.8
HII	4.1	78.4	21.6	58.2	29.9	11.9	30.4	27.8	20.2	9.7	6.7	5.2
I I	3.4	77.6	22.4	55.8	31.9	12.3	29.4	26.4	21.8	10.1	6.5	5.8
III	2.4	82.7	17.3	63.0	27.2	9.8	31.5	31.5	19.7	7.5	5.0	4.8
Averages Curves												
I	25	71.1	28.9	49.3	36.7	14.0	25.0	24.3	21.8	14.9	7.7	6.3
II	25	74.1	25.9	54.2	32.3	13.5	27.1	27.1	19.9	12.4	7.4	6.1
Increase and Decrease												
		1	2	1	2	3	1	2	3	4	5	6
Increase		2	1	2	0	1	2	3	0	0	1	1
Decrease		1	2	1	3	2	1	0	3	3	2	2

TABLE 13
Numbers Paired with Syllables

		Halves		Thirds			Sixths					
Sub.	P	1	2	1	2	3	1	2	3	4	5	6
N I	13.0	58.2	41.8	42.3	37.2	20.5	27.2	15.1	15.9	21.3	9.3	11.2
NII	7.0	53.9	46.1	38.6	31.2	30.2	24.5	14.1	15.3	15.9	17.0	13.2
O I	17.0	60.6	39.4	37.4	41.3	21.3	23.5	13.9	23.1	18.1	10.5	10.8
OII	9.0	57.4	42.5	39.4	38.4	22.5	21.9	17.5	18.0	20.1	10.4	12.1
M I	12.7	68.5	31.5	46.4	36.1	17.6	28.1	18.3	22.1	14.0	4.1	13.4
MII	9.3	72.2	27.8	52.3	34.7	13.0	34.2	18.1	19.9	14.8	8.5	4.5
Averages Curves												
I	12	62.5	37.5	42.1	38.2	19.7	26.3	15.8	20.4	17.8	8.0	11.7
II	12	61.2	38.8	43.5	34.6	21.9	26.9	16.6	17.7	16.9	11.9	10.0
Increase and Decrease												
		1	2	1	2	3	1	2	3	4	5	6
Increase		1	2	2	0	1	1	1	0	2	2	2
Decrease		2	1	1	3	2	2	2	3	1	1	1

Figures in the tables for increase and decrease represent the number of subjects for whom either of these took place in the fractional parts for the averages in the last half of the curves.

B. *Graphical Representations of Specific Points in Individual Curves for the Whole Period of Practice*

(Plates I, II, and III)

In order to get a more detailed view of changes in the curves from day to day, graphs have been drawn showing the percentages reproduced for the first, second, third, fourth, and fifth

sixths of the presentations or effort expended at each practice period for each subject. Only results of the subjects who had the greatest amount of practice are represented in these graphs.

Nearest the abscissa line in each group of graphs will be found the practice curve, marked P, which represents the effect of practice upon the number of repetitions required to perfectly reproduce the material learned. The number of repetitions are represented on the vertical axis or ordinate and the number of practice periods upon the horizontal axis or abscissa.

The other graphs represent the percentages reproduced at various sixths in the practice periods or curves. Graph I is drawn through the points indicating the percentages reproduced at the practice periods after the first sixth of the time or effort consumed; graph II is drawn through the points indicating the percentages reproduced after the first two sixths or first third of the time or effort consumed; likewise graph III represents the same for the first three sixths or the first half, graph IV for the first four sixths or first two thirds, and graph V for the first five sixths of the time or effort consumed. At the end of the last sixth the points all represent one hundred per cent, hence a graph drawn through them must be a straight line. Percentages are represented on the ordinate and the number of practice periods or, what is the same, the number of memory curves is represented upon the abscissa line. Marked individual variations have been smoothed by using the moving average, taking the numbers by fives.[1] Since this smoothing process left the first two and the last two numbers as they were, we have smoothed these by adding to or subtracting from, as the case may be, the nearest smoothed number one third of the difference between the smoothed and the unsmoothed number next to it. Thus if the numbers were 16, 24, 21, ...; 21 being the first smoothed number the results would be 20, 22, 21, etc.

For the paired nonsense material, we have the graphs for subjects A, B, C, D, and E; for the numbers paired with syllables the graphs for subjects N, O, and M; for the paired meaning material the graphs for subjects G and H; and for the serial nonsense material the graphs of subjects L and M.

[1] King, Elements of Statistical Method, Chap. XV, Sec. 96.

PLATE I

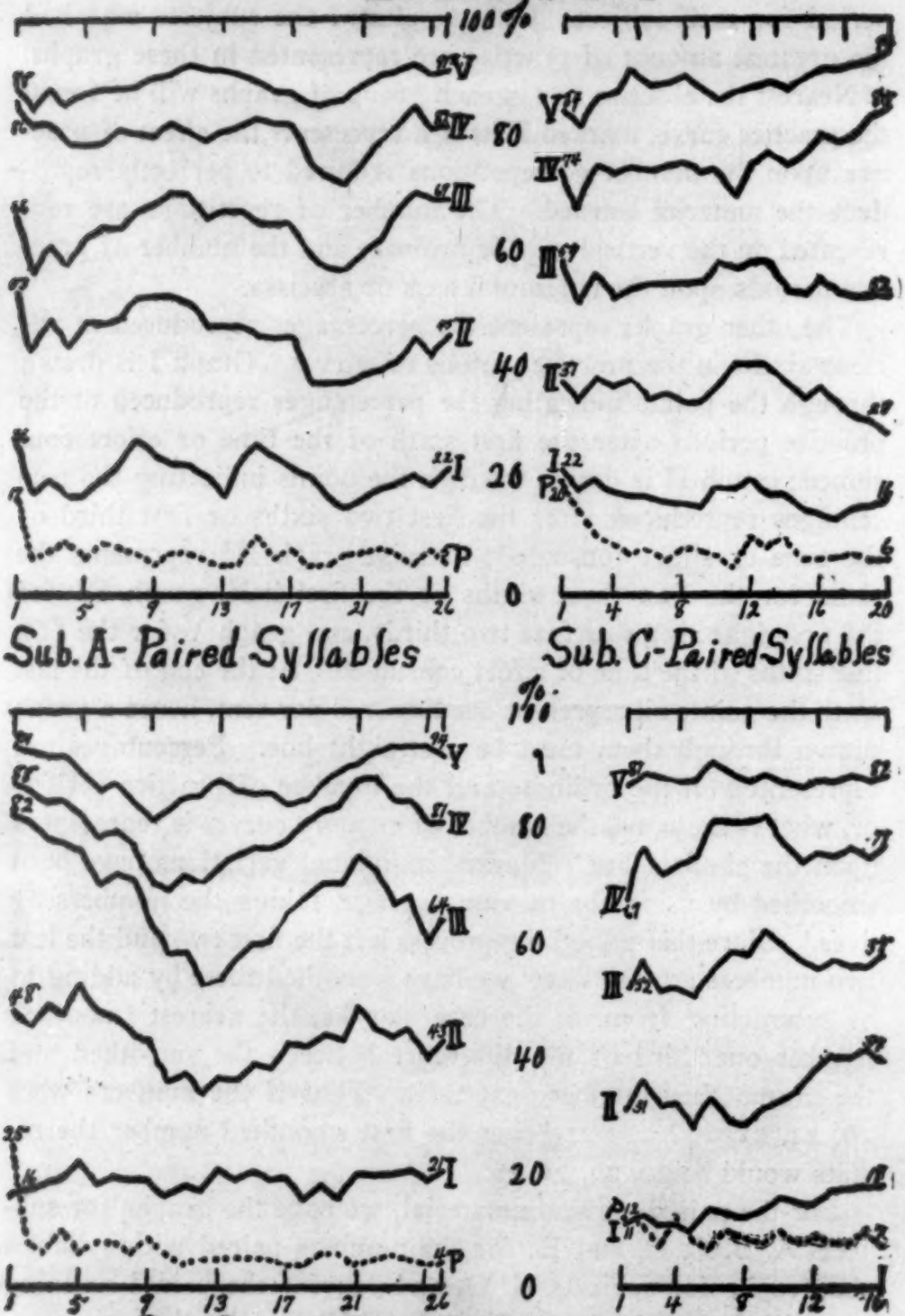
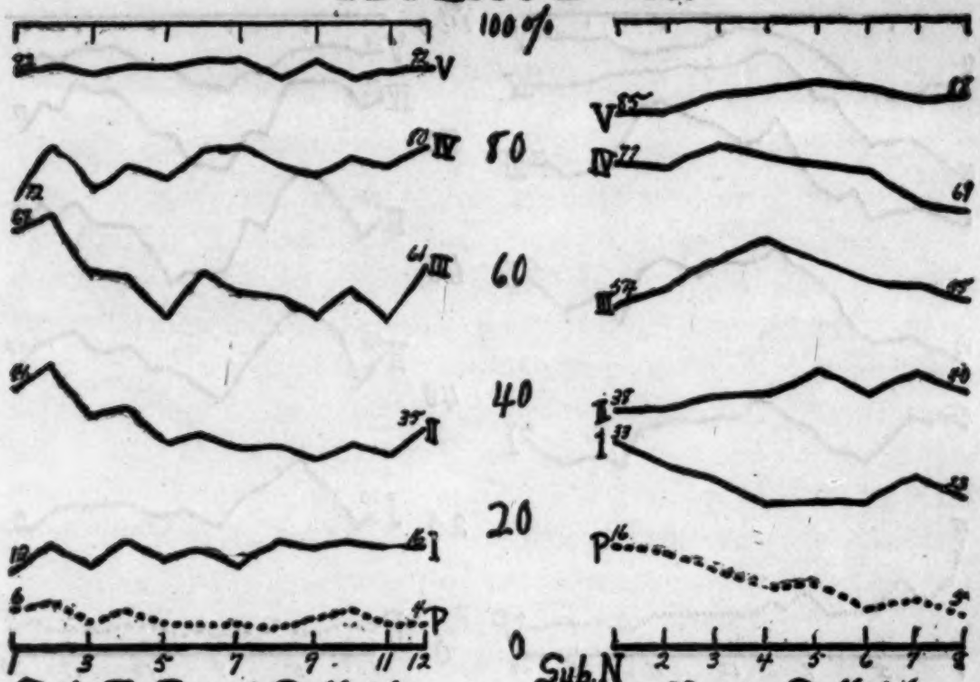
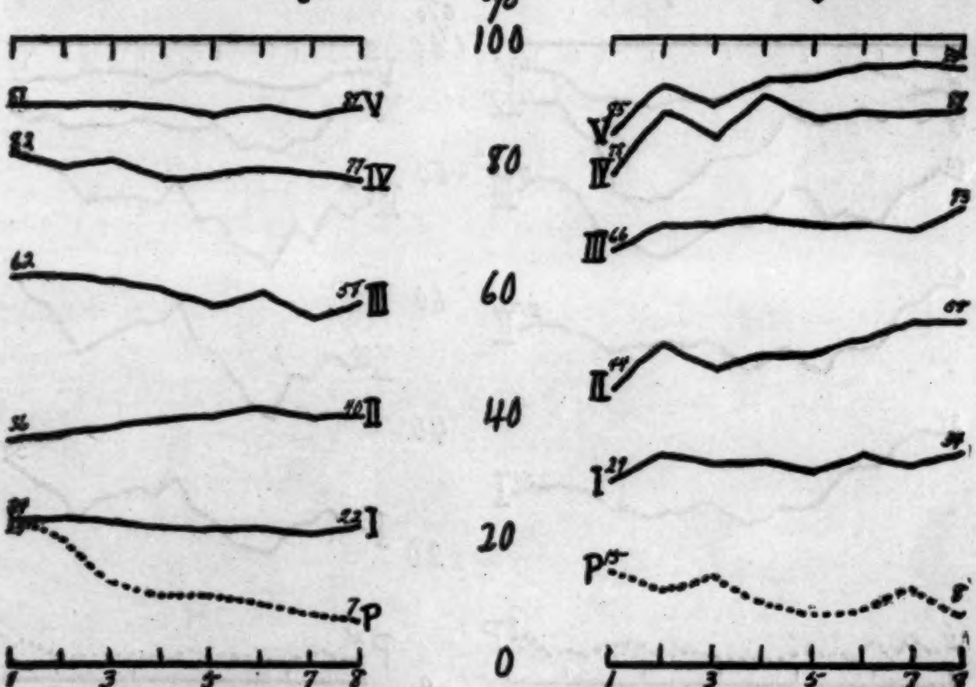

100%
80
60
40
20
0
1 5 9 13 17 21 26
1 4 8 12 16 20
Sub. A - Paired Syllables
Sub. C - Paired Syllables
Sub. B — Paired Syllables — Sub. D

PLATE II.



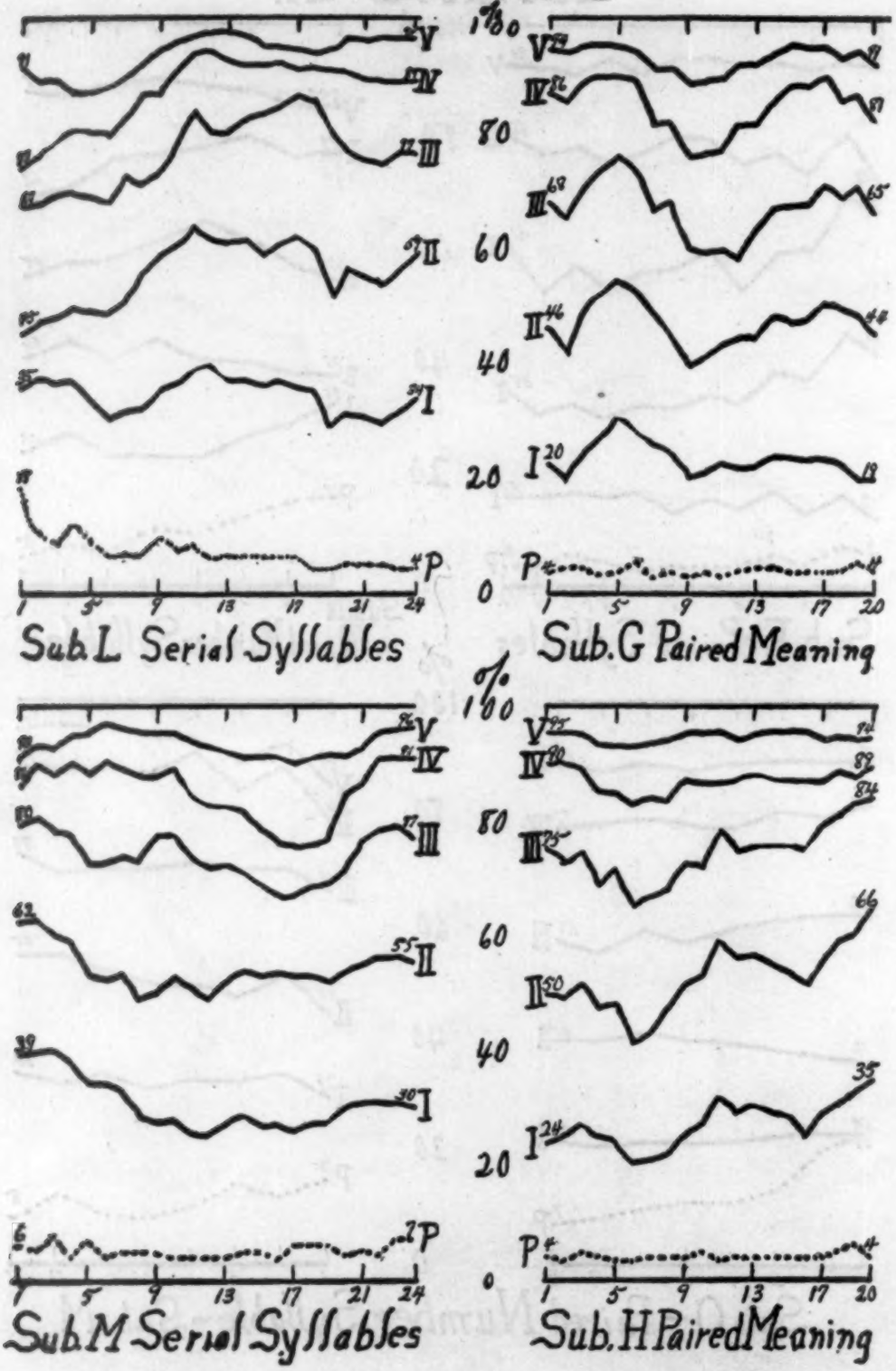
Sub. E - Paired Syllables

Sub. N Paired Number Syllable



Sub O — Paired Number Syllable — Sub. M

PLATE III


%
100
80
60
40
20
0
V
IV
III
II
I
P
1
5
9
13
17
21
24
Sub. L. Serial Syllables
Sub. G Paired Meaning
Sub. M Serial Syllables
Sub. H Paired Meaning

C. *Facts Derived from the Data Above*

(1) The Effect of Practice upon the Number of Presentations or Repetitions required for Memorizing.

A study of the column marked P in the tabulations, Tables 10-13, shows that for most of the subjects there is a marked reduction in the average number of presentations required for the second half of the practice periods in order to get a perfect reproduction of a specific group of material. It is also clear that the amount of reduction depends upon the kind of material practiced upon. In the case of the meaning material, for instance, there is really no reduction at all for our subjects. One shows a slight increase in the last half on the average, one a slight decrease, and one no difference at all. The greatest reduction seems to be found in the case of numbers paired with nonsense syllables. For two subjects the number of presentations are reduced by one half on the average and for one subject by one fourth. In case of the paired and the serial nonsense material, all subjects except one for each group show a substantial reduction in the number of presentations required on the average during the second half of the practice periods. These facts are brought out graphically in greater detail in the P curves found on Plates I, II, and III. The P curves for the paired nonsense material, subjects A, B, C, D, and E, (Plates I and II), all show some effect from practice in the reduction of the number of presentations or reproductions required to reproduce the various materials. The same is found to be true for the number-syllable material, subjects N, O, and M, (Plate II), and the serial nonsense material, subjects L and M, (Plate III). (It will be noted that subject M had practice on two kinds of material. The practice on the paired number-syllable material preceded that of the serial nonsense material. This is not the case for any other subject.) The curves for the paired meaning material, subjects G and H, show again as was indicated in our average tabulations, that there is little if any reduction in the number of repetitions for the practice given. The almost classical initial drop is found in most but not in all of these curves. It appears most prominently in the curves for

subjects A, B, C, O, and L. In the curves for the meaning material, subjects G and H, there is no initial drop.

Bringing the facts presented in our tabulations and graphs together, we may conclude that in general improvement due to practice in the ability to memorize specific kinds of material is evinced by the results for nearly all our subjects. This is, as has been intimated before, in complete accord with common psychological doctrine. We may add that it is clear that the amount of improvement possible is dependent upon the kind or nature of the material practiced upon. The lack of improvement in the meaning material, for instance, for our subjects indicates that the more familiar material will give less practice effect. This simply amounts to saying, however, that this material has already in a sense been practiced upon and for this reason is familiar.

(2) The Effect of Practice upon the Form of the Learning Curves for Memory.

The purpose of the comparisons of the averages for the two halves of each individual subject's results, as well as, the averages of all the curves in each half of the practice periods for each kind of material, (Tables 10-13), is to get some idea of the effect by practice upon the percentages reproduced during each period of halves, thirds, and sixths; hence upon the curves or these particular points in the curves. In a comparative survey of the tables for the two halves of the results for each subject, it is clear that uniformity rather than difference is the outstanding characteristic. It will not do, however, to accept at once this uniformity as evidence of no general change in the curves, for the differences even though they may be small would be significant if they should be found to be running in the same direction at a certain point in the curve for all or most of the subjects. If, for instance, it should be found that all the subjects for a certain specific kind of material should show an increase in the percentage reproduced for the first third with a consequent decrease somewhere else after practice, then it would be fair to conclude that practice does have an influence upon this particular point in the curve.

A survey of the tabulations, however, shows at once that some subjects have an increase while others have a decrease at certain points in the averages for the last half of the practice periods. In order to bring the facts of increase and decrease into a more compact form, we constructed the tables of "Increase & Decrease" given in the tabulations. These tables show the number of subjects having an increase in the average and the number of subjects having a decrease in the average at the various points of the curve for each kind of material during the last half of the practice periods. The table for the paired nonsense material, for instance, shows that for most points about one half of the subjects show an increase and the other half a decrease in the last half of the practice periods. In the case of the serial nonsense material four of the five subjects show an increase in the last half for the second and third sixth of the presentations. However, the uniformity found in the table of averages for this material robs this fact of any significance that might be attributed to it. The tables of increase and decrease for the meaning and the number-syllable material are of little value except to show that for these few subjects there is no uniformity and that the variations are likely due to chance or individual differences.

The four tables of averages given in the tabulations were made from averages of all the curves for each kind of material. The number of curves from which the averages were made is given in the first column. The averages for the first half of the practice periods are marked I and those for the second half are marked II. It will be seen that the uniformity between the two halves is even more striking in these general averages for each kind of material.

In order to summarize, the following averages from the four tables of averages and the totals from the tables of increase and decrease are given. In Table 14, row I thus gives the averages for the first half and row II the averages for the second half of the practice periods or curves of seventeen subjects with a total of 261 curves. The table of increase, Table 15, shows the number of subjects whose averages were increased and the table of decrease the number of subjects whose averages were decreased for the second half of the practice periods.

TABLE 14

Averages of Averages

		Halves		Thirds			Sixths					
No of Curves		1	2	1	2	3	1	2	3	4	5	6
I	130	66.5	33.5	46.5	35.3	18.2	25.7	20.8	20.0	15.3	8.9	9.3
II	131	67.7	32.3	48.2	34.2	17.6	26.4	21.7	19.6	14.7	9.3	8.3

TABLE 15

Increase and Decrease—Totals

	1	2	1	2	3	1	2	3	4	5	6
No. Increase	9	8	11	8	5	8	11	7	7	7	7
No. Decrease	8	9	6	9	12	9	6	10	10	10	10

The averages for the two halves of the practice periods shown in these general average tables present results which indicate a rather remarkable uniformity, the table of increase and decrease shows that about one half of the subjects have averages in the second half which are above those in the first half while for the other half of the subjects the opposite is true. Both of these results argue very much against any possible uniform change in the curve as a result of practice.

While these tabulations are fresh in mind, it may be well to call attention to another problem upon which these results will have a bearing. It will be remembered that there was in most cases a considerable reduction in the number of presentations required for learning a group of material after practice. The reduction was especially marked in case of the number-syllable material. Now it would be natural to infer that the memory curve which resulted from 15 or 20 repetitions might be very different in form from one that resulted from 5 or 10 repetitions. Now if we find that there is no change in the form of the curve due to practice while there is a change in the number of repetitions required then it would follow that the form of the curve is not effected by the number of repetitions required in learning. This, it will be remembered, seems to be the situation. The number-syllable material in which the number of presentations was reduced by almost one half in the second half of the practice did not show any more of a change in the form of the curve than the meaning material in which there was no reduction in the number of repetitions.

The facts, as shown in the tabulations of averages by halves

above, are presented in greater detail in the graphs on Plates I, II, and III. These show the percentages reproduced at various sixths for each individual memory curve and for the whole period during which practice was continued.

Before taking up the question of practice effect upon the curves as shown in the graphs, permit us to digress from the main topic to point out some prominent features in the graphs. The marked periodic variations found in the results of some of the subjects are here brought into prominence. In the graph of subject B this is more evident than in those of other subjects. If, for instance, we compare the points in curve 12 or 13 of graph III with the points in curve 5 or 21, it is quite evident that these are quite different in form. The midpoint of curve 12 is near the 50 per cent line while those of curves 5 and 21 are near the 75 per cent line. It is clear that curve 12 comes nearer to being a straight line than any of the others. This indicates that in a group of memory curves great individual variations are to be expected. Another prominent phase of the graphs of this subject is the marked gradual drop in graphs II, III, IV, and V from period or curve 5 to 12; and the gradual rise again from period or curve 12 to 21. Some of the other graphs show gradual changes of a similar nature but these are not so prominent. For these variations we have no explanation to offer. They can hardly be due to changes in the methods of memorizing, for that would not likely give such a progressive and continuous change for such a large number of periods. Nor can they be attributed to practice since the change is first in one direction and afterwards in another. The marked parallelism throughout their course is quite evident in the graphs of most of the subjects. A careful survey of the plates indicates that in practically every one of them graphs I and V are much less variable and approach much nearer to a straight line than the intervening graphs II, III, and IV. This indicates that the memory curves tend to be more uniform at the beginning and near the end than at the midpoints. This, however, is to be expected since they must all begin at zero and end at one hundred.

Returning to our problem of practice effect upon the percent-

ages reproduced at various sixths it will be best to consider the graphs of each subject separately. Due to the possibility of periodic variations in the graphs it is rather difficult to draw any definite conclusions. Some observations, however, upon this point will be in place even if we have to depend in the main upon the tabulation of averages for more definite conclusions.

For subject A, graph II is the only one which in any sense shows anything like a consistent change that might be attributed to the effect of practice; this being an apparent decline from the beginning to the end.

For subject B, Plate I, we find a rather interesting and variable group of graphs. Graphs III, IV, and V start far up and move down more or less parallel to one another; graph V to the ninth period, graph IV to the tenth, and graph III to the twelfth period. Graphs IV and V come up again to their original level while graph III seems to remain on a much lower level. If this graph is to correlate with graphs III of the other subjects it is not likely that it would ever come up again to its original high level.

For subject C, Plate I, graphs IV and V seem to indicate a slight decline from their original level. It will be noted, however, that this change is found principally from the thirteenth period on, so that if we take into consideration the possible periodic variations this feature looses much of what might be considered a practice effect.

For subject D, graphs I, II, and III appear to rise slightly from their original level. It is likely that graph I would maintain a higher level due to the fact that it starts on a comparatively low level.

For subject E, graphs II and III appear to tend towards a lower level. The same is true for graphs I and IV of subject N. For subjects O and M, there are no pronounced changes in any of the graphs. In general the graphs of subjects E, N, O, and M, (Plate II), are very regular and have only a very few slight variations.

For subject G, Plate III, nothing that can be called a permanent change in the graphs is found; while for subject H, graphs I, II, and III appear to rise from their original level.

For subject L, Plate III, all the graphs except graph I seem to rise from their early level; while for subject M, (serial nonsense material), graphs I and II appear to fall from their early level.

It may be observed that in most cases where there is any change in the graphs that might be interpreted as evidence of practice effect, this change is in no case very large. In the following table, (Table 16), we have brought all these possible changes together for comparison. The Roman numerals at the head of each row designates the graphs for which the following changes occur. The letter indicating the subject is found at the top of each column. A zero indicates no change, D a possible decline, and R a possible rise from the original level.

TABLE 16

	Paired Nonsense					Number-syllable			Meaning		Serial	
	A	B	C	D	E	N	O	M	G	H	L	M
I	O	O	D	R	O	D	O	O	O	R	O	D
II	D	D	D	R	D	O	O	O	O	R	R	D
III	O	D	D	R	D	O	O	O	O	R	R	O
IV	O	O	R	O	O	D	O	O	O	O	R	O
V	O	O	R	O	O	O	O	O	O	O	R	O

The table shows quite clearly that, even if we accept the possible or seeming changes in the graphs as evidence of practice effect, they appear in only some of the curves for some of the subjects and in no case does the same type of change occur uniformly for any one graph for all the subjects in the same material. If there is any practice effect, the most that can be said for it is that it is something that occurs for only some subjects and is of a particular kind for that subject alone. Even this position is questionable when we note the periodic variations that occur in the graphs.

Combining the facts brought out in the graphical representations and those from the tabulations of averages by halves, we are lead, it seems, to but one conclusion, and that is, that while individual curves may vary from time to time to a very large extent, anything that can be called a uniform permanent effect or change in the curve resulting from practice does not occur.

Concluding Statements

The survey of the results relative to practice effect upon the number of repetitions and the form of the memory curve have led us to the following conclusions:

1. The effect of practice upon any material of the same kind and the same length results in a reduction of the number of repetitions required to reproduce accurately equal amounts of that specific kind of material.

2. The amount of reduction in each case is dependent upon the kind or nature of the material and the subject concerned.

3. The form of the memory curve for any individual and for any kind of material, may vary for any individual curve and slightly for longer periods; but anything like a general change in the form of the curve does not occur as a result of practice.

4. A change in the number of repetitions required for memorizing does not have any influence upon the form of the memory curve.

Sec. 2. Individual Differences in Memory Curves.

Do the learning curves for memory differ in form for different individuals?

To answer this question it was necessary to adopt some method of comparing the curves of different subjects. Two difficulties presented themselves. In the first place, the curves were found to be so much alike that a graphical comparison would not bring out the differences, if there were any. In the second place, it was not easy to bring together a number of individual curves in such a way as to make comparison possible.

The first difficulty has been overcome in part by again resorting to the tabulation method. Specific points in the average curve of each subject were selected and the different individual curves were thus compared by comparing these specific points.

In the following tables, (Tables 17-24), these specific points for each subject are tabulated so as to make it possible to compare them with those of other subjects who memorized the same material. In the first table, (Table 17), will be found the tabulations from the subjects who memorized the paired nonsense ma-

terial of 12 pairs each. In the first column, marked Sub., is found the letter of the alphabet designating the subject; in the second column, marked C, the number of individual curves for the subject from which his average curve was determined; in the third column, marked P, the average number of repetitions required by the subject in order to reproduce accurately the twelve syllables. Following these in the columns marked halves, thirds, and sixths will be found the average percentages reproduced by each subject in halves, thirds, and sixths of the time or effort expended. In the same way the various points for the subjects using the other kinds of materials are tabulated.

Tabulations of Averages for Individual Subjects in halves, thirds, and sixths for the Study of Individual Differences. Tables 17 to 24.

TABLE 17

Paired Nonsense Material, (12 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
A	26	7.1	64.7	35.3	45.8	34.4	19.8	21.2	24.6	18.9	15.5	8.8	11.0
B	26	6.5	67.9	32.1	43.5	36.5	20.0	18.9	24.6	24.4	12.1	8.5	11.5
I	6	4.3	66.3	33.7	45.6	35.3	19.1	22.3	23.3	20.7	14.6	9.9	9.2
E	12	4.8	58.5	41.5	34.7	41.5	23.8	15.2	19.5	23.8	17.7	15.6	8.2
D	16	9.0	55.8	44.2	33.5	42.3	24.2	13.8	19.7	22.3	20.0	12.3	11.9
C	20	8.4	55.3	44.7	35.4	40.8	23.8	17.2	18.2	19.9	20.9	13.6	10.2
F	6	4.8	54.4	45.6	34.4	39.9	25.7	13.4	21.0	20.0	19.9	11.9	13.8
G	6	4.7	57.9	42.1	36.1	42.1	21.8	13.9	22.2	21.8	20.3	13.8	8.0
H	6	3.5	60.2	39.8	31.5	46.6	21.9	5.7	25.8	28.7	17.9	12.8	9.1

TABLE 18

Serial Nonsense Material, (12 Syllables).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
R	12	8.6	70.2	29.8	57.6	23.9	18.5	42.2	15.4	12.6	11.3	8.9	9.6
K	6	2.5	67.4	32.6	43.6	36.6	19.8	21.6	22.0	23.8	12.8	9.9	9.9
J	6	5.0	74.1	25.9	64.3	16.2	19.5	41.7	22.6	9.8	6.4	10.8	8.7
M	24	5.1	73.6	26.4	54.2	30.8	15.0	30.5	23.8	19.3	11.5	8.1	6.8
N	6	4.2	77.2	22.8	62.8	23.5	13.7	37.0	25.8	14.4	9.1	7.0	6.7
Q	9	6.1	71.0	29.0	53.9	30.2	15.9	33.1	20.8	17.1	13.1	8.2	7.7
P	10	5.3	69.7	30.3	55.5	29.2	15.3	32.8	22.7	14.2	15.0	8.2	7.1
O	6	5.2	69.9	30.1	58.9	22.9	18.2	36.7	22.2	11.0	11.9	11.3	6.9
S	6	4.7	68.6	31.4	53.6	28.3	18.1	31.7	21.9	15.0	13.3	9.3	8.8
L	24	7.0	76.6	23.4	56.2	31.2	12.6	34.6	21.6	20.4	10.8	6.6	6.0

TABLE 19

Paired Numbers and Syllables, (9 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
M	8	11.0	70.4	29.6	49.4	35.4	15.2	31.2	18.2	21.0	14.4	6.3	8.9
N	8	10.0	56.1	43.9	40.5	34.2	25.3	25.9	14.6	15.6	18.6	13.1	12.2
T	6	5.7	58.6	41.4	29.3	36.9	23.8	22.6	16.7	19.3	17.6	9.5	14.3
O	8	13.0	59.0	41.0	38.4	39.7	21.9	22.7	15.7	20.6	19.1	10.5	11.4

TABLE 20
Paired Numbers and Syllables, (12 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
M	6	8.2	67.3	32.7	44.6	32.8	22.6	27.2	17.4	22.7	10.1	14.6	8.0
N	6	8.2	65.4	34.6	50.1	26.4	23.5	31.8	18.3	15.3	11.1	15.0	10.5
Q	6	9.7	64.4	45.6	42.3	32.8	24.9	21.7	20.6	22.1	10.7	14.5	10.4
T	6	4.8	53.6	46.4	31.5	41.2	27.3	11.7	19.8	22.1	19.1	15.3	12.0
P	6	9.8	66.1	33.9	48.3	30.3	21.4	28.5	19.8	17.8	12.5	16.3	5.1

TABLE 21
Paired Meaning Material, (18 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
D	6	6.7	64.3	35.7	39.0	40.2	20.8	14.7	24.3	25.3	14.9	7.7	13.1
I	10	2.9	80.2	19.8	59.4	29.6	11.0	30.5	28.9	20.8	8.8	5.7	5.3
G	20	3.2	66.7	33.3	46.6	37.6	15.8	22.8	23.8	20.1	17.5	8.6	7.2
H	20	4.2	75.0	25.0	53.3	33.9	12.8	27.3	26.0	21.7	12.2	7.3	5.5

Sub. = Subject; C = curves; P = Number of presentations.

TABLE 22
Paired Nonsense Material, (18 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
B	3	5.2	69.2	30.8	49.5	34.9	15.6	29.0	20.5	19.7	15.2	6.8	8.8
D	5	9.6	59.3	40.7	41.7	33.3	25.0	12.0	29.7	17.6	15.7	17.2	7.8
C	4	8.0	54.2	45.8	35.2	44.8	20.0	17.4	17.8	19.0	25.8	9.5	10.5

TABLE 23
Paired Nonsense Material, (36 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
E	3	7.0	76.2	23.8	54.9	33.8	11.3	23.2	31.7	21.3	12.5	6.7	4.6
D	6	10.5	61.5	38.5	38.7	40.7	20.6	12.9	25.8	22.8	17.9	13.6	7.0

TABLE 24
Serial Nonsense Material, (18 Pairs).

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
N	6	4.5	72.3	27.7	54.1	28.9	17.0	30.8	23.3	18.2	10.7	7.8	9.2
Q	6	7.7	78.8	21.2	59.6	32.7	7.7	30.5	29.1	19.2	13.5	4.2	3.5
P	6	6.2	78.3	21.7	58.8	30.7	10.5	38.6	20.2	19.5	11.2	6.2	4.3

Sub. = subject; C = curves; P = Number of presentations.

Individual Differences Indicated by the Tables.

A. Number of Repetitions: A glance over the columns marked P makes it clear that there is considerable difference in the number of repetitions required by different subjects in order to reproduce the same material. Some of the subjects require as much as three times the number of repetitions required by others. This fact is in accord with common observations and may be due to individual differences in general or to method or to both.

B. Individual Differences in the Percentages Reproduced at Various Intervals During the Learning, Hence in the Form of the Memory Curves.

Turning our attention to this, our main problem, a conclusion is not so easily reached. Certain types of uniformity are evident at first sight (Tables 17-24). The columns, indicating the percentages reproduced by halves, show that every one of the subjects compared reproduced from ten to forty percent more during the first half than during the second half of the effort expended. It is evident, therefore, that there is for all these subjects a flattening of the curve in its upper half. In this sense, at least, there is uniformity. Turning to the columns showing the percentages reproduced by thirds, we find again that every one of the subjects agree in that the smallest percentage is reproduced during the last third. The same uniformity does not hold, however for the first and second third. Here variations are found not only for different materials but for different subjects as well.

Turning to the table for the paired nonsense material, (Table 17), we find that three subjects, A, B, and I, uniformly reproduced almost ten per cent more during the first than during the last third. The other six subjects, on the other hand, reproduced from five to fifteen per cent more during the second than they did during the first third. It is evident that the steepest part of the curves for the six subjects is in the middle third while that for the three subjects A, B, and I is in the first third. Turning to the reproductions by sixths, we get the variations somewhat more in detail. Subjects A, B, and I are again marked off from the others by the larger percentages reproduced in the first and second sixth and the much smaller percentages reproduced in the fifth sixth. It looks somewhat as if we had two types of learners here, one group reproducing the most during the first third of their effort and the other reproducing the most during the middle third. Besides the differences noted above for the two groups, subject H stands alone in the very low percentage reproduced in the first sixth of his time or effort. These are the principal variations found in this table, but other minor differences for each individual will, upon a careful study, reveal themselves.

In the serial nonsense material, (Table 18), no such differences, as noted above, can be found. In the case of thirds, all subjects

agree in that the largest percentage is reproduced in the first third. In all cases except one, over fifty percent is reproduced in this third. In the case of the sixths, all these subjects except one agree in that the largest percentage is reproduced in the first sixth and the second largest in the second sixth. A rather marked uniformity is found in the fifth and last sixths, while some variation is found in the third and fourth sixths. On the whole, it seems that the subjects in this material are very uniform in the form of their curves as shown by the tabulations.

In the paired number-syllable material, (Tables 19 and 20), both the 9 and the 12 pairs, the variations are somewhat more prominent. Even here, however, considerable uniformity is found. The tabulations show that for most of the subjects in these materials the largest percentage is reproduced in the first third while in all cases the smallest percentage is reproduced in the last third. In the 9 pair material, all the subjects reproduced the largest percentage in the first sixth but this is in most cases only slightly above that reproduced in some of the other sixths. In the 12 pair material, a rather uniformly large percentage is reproduced by all the subjects in the fifth sixth, while in the other sixths minor variations are found.

The number of subjects are rather limited for the other kinds of material. The number of curves from which each subjects average is made up are also few in number. We leave these tables, (Tables 21, 22, 23, and 24), to speak for themselves. In general they indicate considerable variation for different subjects, while at the same time much uniformity is evident.

Certain general features in the tabulations for each kind of material bring out some uniformities which must not be overlooked. These have more bearing on the question of variation in the form of the curves due to differences in material, but will be referred to here in as much as they also have a bearing on the question of individual differences.

The following diagrams, (Table 25), have been constructed to bring out some of these features. The Roman numerals over each column indicate the respective sixths in the curve. The

TABLE 25

Paired Nonsense Material, 12 Pairs.

	II	III	IV	I	V	VI
1	5	3	1			
2	2	4	1	2		
3	2	2	4	1		
4			3	4	2	
5				1	4	4
6				1	3	5
Av.	22.1	22.3	17.7	15.5	11.9	10.3

Serial Nonsense Material.

	I	II	III	IV	V	VI
1	9		1			
2		10				
3	1		6	2	1	
4			2	7	1	
5			1		7	2
6				1	1	8
Av.	34.3	21.9	15.7	11.5	8.8	7.8

Syllables and Numbers (9 pairs)

	I	III	IV	II	VI	V
1	4					
2		3	1			
3		1	2	1		
4			1	3		
5					3	1
6					1	3
Av.	25.6	19.1	17.4	16.3	11.7	9.9

Syllables and Numbers (12 pairs)

	I	III	II	V	IV	VI
1	3	2				
2	1	1	3			
3		2	2		1	
4				5		
5					4	1
6	1					4
Av.	24.2	20.0	19.2	14.7	12.7	9.2

Paired Meaning Material, 18 pairs

	I	II	III	IV	V	VI
1	2	1	1			
2	1	3				
3			3	1		
4	1			3		
5					3	1
6					1	3
Av.	23.8	25.7	22.0	13.4	7.3	7.8

Arabic numerals in the vertical column at the head of each row designate the position of each sixth as to the percentage learned. To illustrate: In the diagram for the paired material, the figure 5 under Roman II and after Arabic 1 shows that five subjects reproduced the largest percentage in the second sixth. Likewise the figure 1 after Arabic 6 and under Roman I shows that one subject reproduced the smallest percentage in this sixth. In the last line in each of these diagrams will be found the average percentages reproduced by these subjects for each sixth of the time or effort used.

These diagrams show quite clearly that we have considerable uniformity in the general aspects of the curves for all subjects in each kind of material. They also show that the averages for all the subjects in each kind of material are a good indication of the trend of the curve for most of the subjects. It is also clear that some subjects vary slightly from this average trend and the number of these are indicated in part by the diagrams. To illustrate:

The diagram for the serial nonsense material shows that for most of the subjects there is a gradual reduction in the percentages reproduced from the first to the last sixth. This is quite clearly shown by the fact that the largest numbers are found on the diagonal. At the same time, a few subjects vary from this order. One subject, for instance, reproduced the largest percentage in the third sixth while all the others reproduced the largest percentage in the first sixth. This means that for one subject the steepest part of the curve is not at the beginning but in the third sixth of the curve. The diagonals on the diagrams, where in most cases the largest numbers are found, show the trend of the curves while the numbers on the sides of the diagonal indicate the number of variations. It will be seen that in two out of five kinds of materials, we have been able to retain the regular order of the sixths from the first to the last.

It appears that the uniformity among these subjects is the outstanding fact, when we disregard differences for different materials. This, however, does not permit us to disregard the differences. It may be well in this connection to recall the comparisons made in our discussion of practice effect. Few such marked differences, as we have found here for different subjects, were found between averages of the first and the last half of each subject's curves. If the order, from the greatest to the least per cent reproduced, was from the first to the last sixth in the averages for the first half, this order was in most cases retained in the averages for the last half. On the other hand, we must not stress differences of this type too far. It is well to remember that an interchange of position in this respect may easily take place where the difference between two sixths in all cases is very small. This is quite common in the results from some of the materials used. It is, in fact, little less than remarkable that so many subjects should show such uniformity, as is indicated by the diagrams, when we keep this fact in mind. The close clustering of the subjects around the diagonal, where they are not on the diagonal, in the diagram, is very good evidence of uniformity. The further fact that marked differences occur in the curves for different materials, (See later discussion), while the results

for subjects within a particular material are quite uniform, indicates that individual subjects' differences are after all not so pronounced.

Concluding Statements

1. Individual subjects differ very much in the number of repetitions required in order to reproduce accurately the same material. This difference for some of our subjects is as large as three to one.

2. All subjects reproduced more during the first half of the time or effort expended than during the last half.

3. All subjects reproduced least during the last third of the time. While some subjects reproduced most during the first third others reproduced the largest amount during the middle third.

4. In case of sixths in time or effort, certain minor variations occur but most of the subjects agree in that they reproduced in order from the largest to the smallest percent at almost the same intervals or sixths; the order of the intervals depending upon the kind of material learned.

5. The curves for individual subjects appear to differ very much more for the first sixth than for any other interval of the curve, while the least variation appears to be in the fifth and the second sixths of the curve.

6. In general, we may say that some differences do occur in the curves for individual subjects, but certain uniformities or tendencies are certainly the more prominent facts. These general tendencies appear to differ with the kind of material learned. Of this, more will be said in a later discussion.

Sec. 3. Modifications in the Form of the Memory Curves Due to Variations in the Kind or Nature of the Material.

Sec. 3. Modifications in the Form of the Memory Curves Due to Variations in the Kind or Nature of the Material.

The problem here was to determine whether the form of the curve would change with a change in the material to be learned. The reader has already, in connection with our former discussion, noted some aspects of this question as it appeared in the tabulations for individual differences.

For the comparison of results from different materials, the diagrams given on a former page, (Table 25), are reproduced as they were except that the various sixths are given in the order from first to last. In each of these diagrams, (See Table 26), are found the averages for each sixth of these curves of the subjects for each kind of material.

Since, as has been observed in our former discussion, certain minor differences for individual subjects are found, the results of individual subjects from whom we obtained curves for more than one kind of material have been tabulated for comparative purposes. (See Table 27.) These, together with the individual differences indicated by the diagrams, thus serve as a check upon the averages given. The averages for each kind of material are graphically represented in halves, thirds, and sixths on the plate following the diagrams. (See Plate IV.)

The different materials from which we obtained data for this study are as follows: the paired nonsense, the serial nonsense, the number-syllable, and the meaning material. Beside these, data were obtained from one subject learning consonant syllables paired with nonsense syllables, and from one subject learning the serial consonant syllables of three consonants each.

In all except one case, only one length of each kind of material has been included in this study. The exception is that of the number-syllable material, for which we have included both the 9 and the 12 paired material. Certain uniformities found in each of these help to set off the number-syllable material from the others. The length of material selected in each case was that for which we had the largest amount of data. In the case of the meaning material, this was the paired 18; while in case of all the others it was the 12 paired and the 12 serial material.

In the presentation of the facts bearing upon this question, we are, as noted above, also making use of averages from groups of individual subjects. (Table 27.) The advisability of this procedure might be questioned on the basis of differences found for individual subjects. It should be remembered, however, that the differences, where found, were rather small and that most of the subjects conformed in the general features of

the curves for each kind of material. The validity of the averages, as an indication of the form of the curves, depends upon the degree of uniformity with which different subjects conform to them, as well as the number of subjects concerned.

Our problem here, it will be remembered, is not to determine the absolute form of the curve for each kind of material learned but rather to determine whether there is any evidence of differences in the form of the curves. Our data are not sufficient to establish absolutely the definite form of the curve for each kind of material for an unlimited number of subjects; yet certain uniformities in the curves of subjects using the same kind of material make it possible to point out certain general features of the curves for each.

TABLE 26

Paired Nonsense Material (12 pairs)

	I	II	III	IV	V	VI
1		5	3	1		
2	2	2	4	1		
3	1	2	2	4		
4	4			3	2	
5	1				4	4
6	1				3	5
Av.	15.7	22.1	22.3	17.7	11.9	10.3

Serial Nonsense (12 syllables)

	I	II	III	IV	V	VI
1	9		1			
2		10				
3	1		6	2	1	
4			2	7	1	
5			1		7	2
6				1	1	8
Av.	34.3	21.9	15.7	11.5	8.8	7.8

Number-syllable (9 pairs)

	I	II	III	IV	V	VI
1	4					
2			3	1		
3		1	1	2		
4		3		1		
5					1	3
6					3	1
Av.	25.6	16.3	19.1	17.4	9.9	11.7

Number-syllable (12 pairs)

	I	II	III	IV	V	VI
1	3		2			
2	1	3	1			
3		2	2	1		
4					5	
5				4		1
6	1					4
Av.	24.2	19.2	20.0	12.7	14.7	9.2

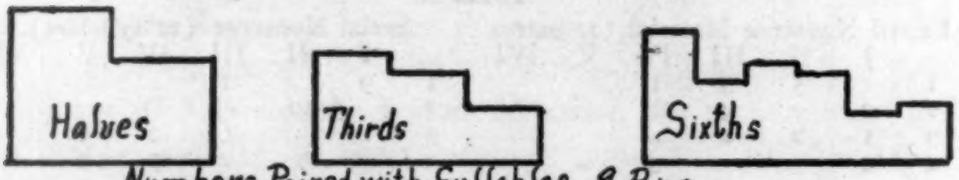
Paired Meaning (18 pairs)

	I	II	III	IV	V	VI
1	2	1	1			
2	1	3				
3			3	1		
4	1			3		
5					3	1
6					1	3
Av.	23.8	25.7	22.0	13.4	7.3	7.8

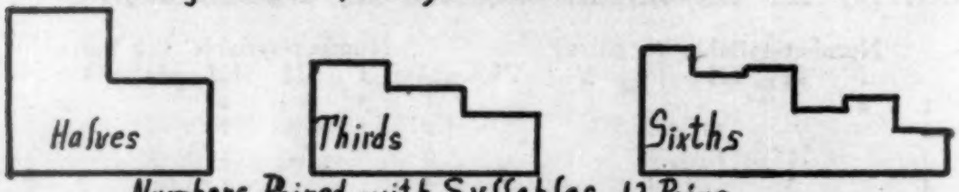
PLATE IV.

Paired Syllables, 12 Pairs. Averages from 9 subjects, 124 Curves.

Serial Syllables, 12 Syllables
Averages from 10 subjects, 109 Curves



Numbers Paired with Syllables, 9 Pairs
Averages from 4 Subjects, 30 Curves



Numbers Paired with Syllables, 12 Pairs
Averages from 5 Subjects, 30 Curves

18 Pairs, Meaning - Averages from 4 Subjects, 56 Curves.

The graphs above show the relative percentages reproduced in halves, thirds, and sixths of the time or effort expended.

TABLE 27

Tabulations from Curves of Individual Subjects to Study Variations Resulting from Different Kinds of Material.

S12 = Results from the 12 Serial nonsense syllables.
N9 = " " " Number-syllable material of 9 pairs.
N12 = " " " " " " " 12 pairs.
M18 = " " " Meaning material of 18 pairs.
PN = " " " Paired nonsense material of 12 pairs.
PC = " " " Paired consonant-syllable material of 12 pairs.
SC = " " " Serial consonant syllables of 12 syllables.
C = the number of curves from which the results are an average.
P = the average number of presentations required for learning.

			Halves		Thirds			Sixths					
	C	P	1	2	1	2	3	1	2	3	4	5	6
Subject M													
S12	24	5.1	73.6	26.4	54.2	30.8	15.0	30.5	23.8	19.3	11.5	8.1	6.8
N9	8	11.0	70.4	29.6	49.4	35.4	15.2	31.2	18.2	21.0	14.4	6.3	8.9
N12	6	8.2	67.3	32.7	44.6	32.8	22.6	27.2	17.4	22.7	10.1	14.6	8.0
Subject Q													
S12	9	6.1	71.0	29.0	53.9	30.2	15.9	33.1	20.8	17.1	13.1	8.2	7.7
N12	6	9.7	64.4	45.6	42.3	32.8	24.9	21.7	20.6	22.1	10.7	14.5	10.4
Subject N													
S12	6	4.2	77.2	22.8	62.8	23.5	15.7	37.0	25.8	14.4	9.1	7.0	6.7
N9	8	10.0	56.1	43.9	40.5	34.2	25.3	25.9	14.6	15.6	18.6	13.1	12.2
N12	6	8.2	65.4	34.6	50.1	26.4	23.5	31.8	18.3	15.3	11.1	13.0	10.5
Subject O													
S12	6	5.2	69.9	30.1	58.9	22.9	18.2	36.7	22.2	11.0	11.9	11.3	6.9
N9	8	13.0	59.0	41.0	38.4	39.7	21.9	22.7	15.7	20.6	19.1	10.5	11.4
Subject T													
N9	6	5.7	58.6	41.4	39.3	36.9	23.8	22.6	16.7	19.3	17.6	9.5	14.3
N12	6	4.8	53.6	46.4	31.5	41.2	27.3	11.7	19.8	22.1	19.1	15.3	12.0
Subject P													
S12	10	5.3	69.7	30.3	55.5	29.2	15.3	32.8	22.7	14.2	15.0	8.2	7.1
N12	6	9.8	66.1	33.9	48.3	30.3	21.4	28.5	19.8	17.8	12.5	16.3	5.1
PC	6	10.5	58.1	41.9	35.0	33.2	31.8	18.6	16.4	23.1	10.1	16.4	15.4
Subject U													
S12	3	2.7	74.2	25.8	56.4	30.8	12.8	28.2	28.2	17.8	13.0	6.5	6.3
SC	6	5.5	54.4	45.6	49.2	27.9	22.9	32.0	17.2	5.2	22.7	13.5	9.4
Subject I													
PN	6	4.3	66.3	33.7	45.6	35.3	19.1	22.3	23.3	20.7	14.6	9.9	9.2
M18	10	2.9	80.2	19.8	59.4	29.6	11.0	30.5	28.9	20.8	8.8	5.7	5.3
Subject H													
PN	6	9.8	60.2	39.8	31.5	46.6	21.9	5.7	25.8	28.7	17.9	12.8	9.1
M18	20	4.0	75.0	25.0	53.3	33.9	12.8	27.3	26.0	21.7	12.2	7.3	5.5
Subject D													
PN	6	9.0	55.8	44.2	33.5	42.3	24.2	13.8	19.7	22.3	20.0	12.3	11.9
M18	6	6.7	64.3	35.7	39.0	40.2	20.8	14.7	24.3	25.3	14.9	7.7	13.1
Subject G													
PN	6	4.7	57.9	42.1	36.1	42.1	21.8	13.9	22.2	21.8	20.3	13.8	8.0
M18	20	3.2	66.7	33.3	46.6	37.6	15.8	22.8	23.8	20.1	17.5	8.6	7.2

Comparing the curves of these materials by the average percentages reproduced by halves, (See graphs Plate IV), it appears that by far the larger percentage is reproduced during the first half for each kind of material. In the actual percentages reproduced, however, they may be divided into two groups; including in the first the serial and the meaning material with averages of 71.9 per cent and 7.15 per cent respectively in the first half, and in the second group the paired number-syllable, both the 9 and the 12 pairs, and the paired nonsense material with averages of 61.0 per cent, 63.4 per cent, and 60.1 per cent respectively for the first half of the time or effort expended.

Comparing the curves of the materials as reproduced on the average by thirds, we may again make the same grouping of the serial and the meaning material. There is here, however, less uniformity between the two although the percentages reproduced from the greatest to the least is from the first to the last third in order. In the second group, the number syllable material show percentages decreasing from the first to the last third; while the paired nonsense material is unique in that the largest percentage is reproduced in the middle third.

Comparing the curves of the materials in greater detail by sixths, we find more variations.

In case of the paired nonsense material the averages, as shown on the graphs, (Plate IV), indicate that the largest percentage is reproduced during the third sixth, but this is only .2 per cent above that of the second sixth. The tabulations for individual subjects, (Table 27), show that this, almost equal percentages for these two sixths, is equally characteristic of the curves for the individual subjects. The same fact is shown in the diagram for this material, (Table 26). The more important fact here, however, is the comparatively small percentage reproduced during the first sixth. Judged either by the average percentages or by the number of subjects for whom it occurs, this sixth comes after the fourth in order from largest to smallest percentage reproduced. (See diagram, Table 26.) Thus it would appear that in this material we have a case where the "initial rise" does not occur. This is true not only for the average but for the

curve of each individual subject who memorized this material. (See Table 27.) The same is true for the curves from this material in greater lengths, i.e., 18, 24, and 36 pairs, as we shall see later. (See Tables 28 and 29, paired nonsense material.)

The graph for the serial nonsense material indicates a somewhat different type of curve. Here the first sixth shows by far the largest percentage of reproduction. This is equally true of curves for individual subjects save one. (See diagram, Table 26.) The same we find to be true for the same material of greater lengths, i.e., 18 syllables. (See Table 28.) The large numbers found on the diagonal, (Table 25), and the close clustering around it of the rest of the numbers representing the number of subjects,—shows further the uniformity for the subjects in the gradual decrease in the percentages of this material reproduced from the first to the last sixth.

The Meaning Material: We have found already by the comparisons of halves and thirds that this material gives a curve most like that for the serial material just discussed. In comparisons by sixths, however the similarity is not nearly so striking. Especially is this fact true for the first sixth in which there is a much lower percentage of reproduction than in that for the serial material. For the meaning the average percent reproduced for the second sixth is nearly 2 per cent higher than that for the first. That this is the prevailing tendency may well be questioned when we take into consideration the curves for individual subjects. In fact it would appear that the first rather than the second sixth gives the largest percentage for most subjects. This is supported as we shall see later by the fact that the same material of 12 pairs results in a curve in which the largest percentage is reproduced in the first sixth. Our data are rather limited but there is, it appears, a gradual decrease in the percentages reproduced from the first sixth to the last which indicates that the curve for this material in this respect is like that of the serial nonsense material. This seems to be true whether measured by the averages or by the curves for individual subjects. The principal difference between the curves for the paired meaning and the serial nonsense material thus seems to be that the former shows a

smaller percentage of reproduction in the first sixth than does the latter.

The Number-Syllable Material: Taking the 9 and the 12 pair materials separately, the data are rather limited as to the number of subjects. Taking these together, however, certain uniformities set them off very clearly from the results of the other kinds of material. It may be said, first of all, that this material gives in every case, average and individual, a curve more nearly approaching a straight line than that of any other with which we have compared it. Still it has a large number of lesser variations which makes the curve more irregular than those for other materials. (See graphs on Plate IV). The averages in both the 9 and the 12 pair materials show that the largest percentage is reproduced in the first sixth and that a larger percentage is reproduced in the third than in the second sixth. Seven out of nine subjects reproduced a larger percentage during the third than during the second sixth. (See Tables 19, 20, and 27.) Thus both the averages and the results for the individual subjects indicate that this fact is characteristic for the curves for this material. At any rate, it is too uniform not to indicate that at this point these curves are different from those of other materials. There are differences between these two materials themselves, but when compared with the uniformities which they present as against the curves for the other materials these differences rather tend to emphasize the points in which they differ from other materials.

The Consonant Materials: From the paired consonant syllable material, we have the average curve for only one subject. It may be interesting to note that this resembles the curve for the paired number-syllable material in that a larger percentage is reproduced in the third than in the second sixth. (See Table 27, Subject P). For the serial consonant syllables, we likewise have the results from six curves of but one subject. This curve is not like that of the serial nonsense but rather like that of the paired number-syllable material.

Concluding Statements

1. For all the materials represented in our experiment, it appears that, although the actual percentages for the different ma-

terials vary, yet the largest percentage is reproduced during the first half of the time or effort expended.

2. Taking the percentages reproduced by thirds, it appears that for all the materials, except the paired nonsense, our subjects reproduced percentages from largest to smallest in order from the first to the last third.

3. In case of the paired nonsense material, our subjects on the average reproduced the largest percentage in the middle third, the initial first third being relegated to second place.

4. Taken by sixths, the order of reproduction from largest to smallest percentages was as follows: Paired Nonsense III or II, IV, I, V, and VI; Serial Nonsense I, II, III, IV, V, and VI; Paired Meaning I or II, III, IV, V, and VI; 12 Paired Number-syllable I, III, II, V, IV, and VI; and the 9 Paired Number-syllable I, III, II or IV, and V or VI.

5. In general the curve for the paired nonsense material is characterized by the *lack of the "rapid initial rise," its steepest parts being in the third and second sixths* after which there is a gradual decrease in the percentages reproduced; the curve for the serial nonsense material differs more from the paired than does that of any other and is characterized by a rapid initial rise after which there is a gradual decrease in the percentages reproduced to the last sixths; the curve for the meaning material is much like that for the serial nonsense, however, the initial rise is spread over the first half of the curve; the curve for the number-syllable material is characterized by the fact that it more nearly approaches a straight line than any of the others, and it is like that for the paired nonsense material in that an almost equal percentage is reproduced in the second as in the third sixth.

Sec. 4. Effect upon the Form of the Memory Curve due to Changes in the Length of the Material.

The problem here was to determine whether a change in the length of the material would produce a change in the form of the curve. By length of material, we here mean the number of syllables or the number of pairs of associates to be learned by the subject. The lengths used were, nine, twelve, eighteen, twenty-

four, and thirty-six. These lengths were tried out for four different kinds of material. (See Table 28 and 29.)

In order to compare the curves for various lengths of material, we have as in the former studies, tabulated the percentages reproduced in halves, thirds, and sixths of the time or effort expended. As in the study for the kinds of materials, we have made use of averages as well as results from individual subjects in the tabulations.

In table 28, we have the averages for all the subjects from whom we obtained curves for different kinds and lengths of material. The different lengths are grouped by materials from which the results were produced, since the curve varies for different materials. The length of the material is designated in each case in the table. In the column marked Subs., will be found the number indicating the number of subjects from whom the curves were obtained; in the column marked C, the total number of curves from which the averages were taken; and in the column marked P, the average number of repetitions required for complete reproduction in each case. The remaining columns give the average percentages reproduced in halves, thirds, and sixths of the time or effort expended.

In table 29, we have the same kind of tabulations as those in table 28, but here the figures are averages for individual subjects from whom curves were obtained for materials of more than one length. The explanations of abbreviations used, given at the head of this table, will make clear its contents.

A. Number of Repetitions: Before taking up a consideration of the form of the curves, a word must be said about the number of repetitions required for the different lengths of material.

The tabulations for the number-syllable material (Table 28), present the rather unusual fact that more repetitions were required for the shorter than for the longer materials. This is, however, the fact, and it is explained by the circumstances that the longer series in every case followed the learning of either the shorter number-syllable material or else some other material, while the shorter material always represents the first work of the subject. The effect of practice thus accounts for this anomalous

TABLE 28

Tabulations of Averages for Materials of Various Lengths.

Paired Number-syllable Material

			Halves		Thirds			Sixths					
Subs.	C	P	1	2	1	2	3	1	2	3	4	5	6
Nine Pairs													
5	36	9.2	58.4	41.6	40.9	36.6	22.5	25.5	15.4	17.5	19.1	10.1	12.4
Twelve Pairs													
5	30	8.1	63.4	36.6	43.4	32.7	23.9	24.2	19.2	20.0	12.7	14.7	19.2

Serial Nonsense Material

			Halves		Thirds			Sixths					
Subs.	C	P	1	2	1	2	3	1	2	3	4	5	6
Twelve syllables													
10	91	5.4	72.0	28.0	56.2	27.2	16.6	34.5	21.7	15.8	11.4	8.6	8.0
Eighteen syllables													
3	18	6.1	76.4	23.6	57.5	30.7	11.8	33.3	24.2	18.9	11.8	6.1	5.7

Paired Nonsense Material

			Halves		Thirds			Sixths					
Subs.	C	P	1	2	1	2	3	1	2	3	4	5	6
Twelve Pairs													
9	124	5.9	60.1	39.9	37.8	40.0	22.2	15.7	22.1	22.3	17.7	11.9	10.3
Eighteen Pairs													
3	12	7.6	60.9	39.1	42.2	37.6	20.2	19.5	22.7	18.7	18.9	11.2	9.0
Twenty-four Pairs													
1	6	77	66.1	33.9	42.8	38.9	18.3	15.4	27.4	23.3	15.6	12.0	6.3
Thirty-six Pairs													
2	9	8.7	68.9	31.1	46.8	37.3	15.9	18.0	28.8	22.1	15.2	10.1	5.8

Meaning Material

			Halves		Thirds			Sixths					
Subs.	C	P	1	2	1	2	3	1	2	3	4	5	6
Twelve Pairs													
2	8	4.3	64.4	35.6	44.6	34.7	20.7	25.0	19.6	19.8	14.9	14.1	6.6
Eighteen Pairs													
4	56	4.2	71.5	28.5	49.5	35.4	15.1	23.8	25.7	22.0	13.4	7.3	7.8

result. The effect of practice is also responsible in some of the other cases for the insignificant increase in the number of presentations with the lengthening of the material. Yet some of the cases can not thus be explained and they indicate that the number of repetitions required is in no way proportional to the length of the material. To get at the actual facts in this matter, it is necessary to turn to the results for individual subjects. Subject D (Table 29), learned the 18 pairs before the 12 pair series, so that the effect of practice would favor the shorter series. Yet the difference in the number of repetitions for the two lengths

TABLE 29
Tabulations from Curves of Individual Subjects for Materials of Various Lengths

N9 = Results from the paired number-syllable material, 9 pairs.
N12 = " " " " " " " 12 pairs.
S12 = " " " Serial nonsense syllables, 12 syllables.
P12 = " " " paired nonsense material, 12 pairs.
P18 = " " " " " " 18 pairs.
P24 = " " " " " " 24 pairs.
P36 = " " " " " " 36 pairs.
M12 = " " " " meaning material, 12 pairs.
M18 = " " " " " " 18 pairs.
S18 = " " " Serial nonsense syllables, 18 syllables.
C = the number of curves from which the averages were taken.
P = the average number of presentations required.

			Halves		Thirds			Sixths					
	C	P	1	2	1	2	3	1	2	3	4	5	6
Subject N													
N9	8	10.0	56.1	43.9	40.5	34.2	25.3	25.9	14.6	15.6	18.6	13.1	12.2
N12	6	8.2	65.4	34.6	50.1	26.4	23.5	31.8	18.3	15.3	11.1	13.0	10.5
Subject M													
N9	8	11.0	70.4	29.6	49.4	35.4	15.2	31.2	18.2	21.0	14.4	6.3	8.9
N12	6	8.2	67.3	32.7	44.6	32.8	22.6	27.2	17.4	22.7	10.1	14.6	8.0
Subject T													
N9	6	5.7	58.6	41.4	39.3	36.9	23.8	22.6	16.7	19.3	17.6	9.5	14.3
N12	6	4.8	53.6	46.4	31.5	41.2	27.3	11.7	19.8	22.1	19.1	15.3	12.0
Subject N													
S12	6	4.2	77.2	22.8	62.8	23.5	13.7	37.0	25.8	14.4	9.1	7.0	6.7
S18	6	4.5	72.3	27.7	54.1	28.9	17.0	30.8	23.3	18.2	10.7	7.8	9.2
Subject Q													
S12	9	6.1	71.0	29.0	53.9	30.2	15.9	33.1	20.8	17.1	13.1	8.2	7.7
S18	6	7.7	78.8	21.2	59.6	32.7	7.7	30.5	29.1	19.2	13.5	4.2	3.5
Subject P													
S12	10	5.3	69.7	30.3	55.5	29.2	15.3	32.8	22.7	14.2	15.0	8.2	7.1
S18	6	6.2	78.3	21.7	58.8	30.7	10.5	38.6	20.2	19.5	11.2	6.2	4.3
Subject H													
M12	3	3.5	70.2	29.8	49.7	31.0	19.3	26.7	23.0	20.5	10.5	10.0	9.3
M18	20	4.0	75.0	25.0	53.3	33.9	12.8	27.3	26.0	21.7	12.2	7.3	5.5
Subject D													
M12	5	5.0	58.5	41.5	39.4	38.3	22.3	23.3	16.1	19.1	19.2	18.3	4.0
M18	6	6.7	64.3	35.7	39.0	40.2	20.8	14.7	24.3	25.3	14.9	7.7	13.1
Subject A													
P12	26	7.1	64.7	35.3	45.8	34.4	19.8	21.2	24.6	18.9	15.5	8.8	11.0
P24	6	7.7	66.1	33.9	42.8	38.9	18.3	15.4	27.4	23.3	15.6	12.0	6.3
Subject C													
P12	20	8.4	55.3	44.7	35.4	40.8	23.8	17.2	18.2	19.9	20.9	13.6	10.2
P18	4	8.0	54.2	45.8	35.2	44.8	20.0	17.4	17.8	19.0	25.8	9.5	10.5
Subject E													
P12	12	4.8	58.5	41.5	34.7	41.5	23.8	15.2	19.5	23.8	17.7	15.6	8.2
P18	3	5.2	69.2	30.8	49.5	34.9	15.6	29.0	20.5	19.7	15.2	6.8	8.8
P36	3	7.0	76.2	23.8	54.9	33.8	11.3	23.0	31.7	21.3	12.5	6.7	4.6
Subject D													
P12	16	9.0	55.8	44.2	33.5	42.3	24.2	13.8	19.7	22.3	20.0	12.3	11.9
P18	5	9.6	59.3	40.7	41.7	33.3	25.0	12.0	29.7	17.6	15.7	17.2	7.8
P36	6	10.5	61.5	38.5	38.7	40.7	20.6	12.9	25.8	22.8	17.9	13.6	7.0

of material is on the average only 1.7 repetitions; there being an average of 5 repetitions for the 12 and 6.7 for the 18 pair material. A decrease of 33 1/3 per cent in the length of the material thus results in a decrease of only 25 per cent in the number of repetitions. This is the only case where the longer material was given after the shorter, but there are a number of other instances in which the effect of practice is eliminated as a factor.

Subject A, after twenty periods of practice on the 12 paired nonsense material, used in the next six periods an average of 6.7 repetitions; following these, six 24 paired nonsense series were learned with an average of 7.7 repetitions. Here then is a case where an increase of 100 per cent in the length of the material required an addition of only 15 per cent in the number of repetitions.

Subject C, after sixteen periods of practice on this 12 paired nonsense material, used in the next four periods an average of 6.3 repetitions; following these, four 18 paired series were learned with an average of 8.0 presentations. An increase of 50 per cent in the length thus required an addition of only 28 per cent in the number of presentations.

Subject D, after eleven periods of practice on this 12 paired material, used during the next five periods an average of 8.1 repetitions; following these, five series of 18 pairs were learned with an average of 9.6 presentations; and following these again were learned six series of 36 pairs with an average of 10.5 repetitions. Thus with an increase of 50 per cent in the length of the material there was an increase of only 18 per cent in the number of presentations, and increasing this material again by 100 per cent of itself resulted in an increase of only 9 per cent in the number of repetitions.

Subject E, after nine periods of practice on this 12 paired material, used in the next three periods 4.7 presentations on the average; following these, three series of 18 pairs were learned with an average of 5.2; following these again, three series of 36 pairs each were learned with an average of 7 repetitions. Thus for this subject there was, with an increase of 50 per cent in the length of the material, an increase of only 11 per cent in

the number of presentations; while increasing this material again by 100 per cent of itself there was an increase of only 35 per cent in the number of repetitions.

From these facts it would appear that with an increase in the length of the material there was only a relatively small increase in the number of repetitions required to learn the longer series.

The same fact may be shown by a comparison of the best records made for each length of material. The best record made by Subject A, in the twenty-six series of 12 paired material, was 5 repetitions; while in the six series of 24 pairs he also made a record of 5 repetitions. The best record made by subject C in the twenty series of 12 pairs was one of 5 presentations; while in the four series of 18 pairs one record of 6 repetitions was made. The best record of D in the sixteen series of 12 pairs was 7 repetitions; in the five series of 18 pairs 8 presentations; and in the six series of 36 pairs also 8 repetitions. The best record made by subject E, in the twelve series of 12 pairs, was 3 presentations; in the three series of 18 pairs 4; and in the three series of 36 pairs 6 repetitions.

These facts indicate quite convincingly that the number of repetitions are not proportional to the length of the material in the case of paired associates. In other words, they indicate that one can learn series of 18, 24, and 36 pairs with only a very slight increase in the number of repetitions required for series of 12 pairs each. This does not mean, however, that one can learn these longer series in almost the same length of time, since it takes more time to repeat a series of 18 or 36 pairs than a series of 12 pairs. The actual time may be calculated by multiplying the number of pairs in the series by 8, the number of seconds required to present and attempt to recall each pair of syllables. In the following table, we give the actual time required on the average to reproduce the various lengths for the above subjects. In the table, we have also included the results from two subjects who learned two lengths of the serial nonsense syllables. Av.P. = the average number of repetitions.

TABLE 30

Tabulations of the Average Number of Repetitions and of the Time Required for Materials of Various Lengths.

Length of Material	Subject	Av. P	Time in minutes
Paired nonsense 12	A	6.7	11
Paired nonsense 24	A	7.7	25
Paired nonsense 12	C	6.3	10
Paired nonsense 18	C	8.0	19
Paired nonsense 12	D	8.1	13
Paired nonsense 18	D	9.6	23
Paired nonsense 36	D	10.5	65
Paired meaning 12	D	5.0	8
Paired meaning 18	D	6.7	16
Paired nonsense 12	E	4.7	7
Paired nonsense 18	E	5.2	13
Paired nonsense 36	E	7.0	34
Serial syllables 12	Q	5.4	13
Serial syllables 18	Q	7.7	24
Serial syllables 12	N	4.2	8
Serial syllables 18	N	4.5	11

In the above table, we have the data for only these six subjects, since they were the only cases where, on account of preceding practice, we felt positive that the effect of practice did not enter as a factor. We may add that subject N may have experienced a slight practice effect due to the fact that most of the preceding practice had been upon the number-syllable material. In spite of the limited number of subjects, this table is quite suggestive in that the results in the time required for the various length of material is proportionately uniform for the subjects given.

Comparing the cases where the length of material is changed from 12 to 18 pairs or syllables, we find the time almost doubled for each subject; for subject C it is increased from 10 to 19 minutes, for subject D from 13 to 24 minutes, for subject E from 7 to 13 minutes, for subject Q from 13 to 24 minutes, and for subject N from 8 to 11 minutes. Where the length of the material is increased from 12 to 36 or three times, we find the time increased almost five times; for subject D from 13 to 65 minutes and for subject E from 7 to 35 minutes.

It thus appears, that while the actual time varies for different

subjects the relative or proportionate increase in time for the different lengths of material is strikingly uniform.

B. The Effect of the Length of Material upon the Form of the Memory Curve

Turning to our main problem, we find that the table of averages (Table 28), indicates a rather striking uniformity for the curves from the various lengths of each kind of material. A survey of the columns shows, as we have found before, that, while the curves vary a good deal for the different kinds of material, the variations for the different lengths of the same material are comparatively insignificant. At the same time, some features of change are found in the results which, though rather small, are worthy of our consideration.

Table 28 indicates that in every case for all the materials there is, with an increase in their length, a slight increase in the percentages learned in the first half, the first third, and the second sixth of the time or effort expended. This fact would indicate that there is a tendency to increase slightly the percentages reproduced in the early part of the learning in case of the longer material. It will be found, however, upon inspection of the tabulations for individual subjects, that this is true only in nine out of the thirteen cases. (Table 28.) In four cases, we find a decrease in the percentages reproduced during the first half, first third, and second sixth. This variation, connected with the fact that in the case of the averages the increase in most cases are rather small, makes this apparent tendency less significant.

It is clear, both from the table of averages and those of individual subjects, that the general form of the curves is in all cases very much the same for one length of material as for another; in most cases the curves are very much alike even in the smaller details.

If we survey the percentages reproduced by sixths, more variations are found for the different lengths of the number-syllable material than in those of the other materials. Yet these percentages are alike for the different lengths in most respects. In both the 9 and the 12 pair material, the largest percentage is re-

produced in the first sixth, and a larger percentage is reproduced in the third than in the second sixth. In the last sixth differences are found for each length which vary for different individuals although the averages for both lengths show a larger percentage of learning in the last sixth than in the fifth sixth.

The two lengths of the serial nonsense material result in almost identical curves.

The four lengths of the paired nonsense material result in curves very much alike. The most characteristic difference is a slight increase in the percentages reproduced in the last sixth as the length of the material is increased.

In case of the meaning material, some differences are found. These differences, it will be observed, are due in the main to the peculiarities found for subject D whose curves for the 18 pairs were quite different from those for the 12 pair material.

Concluding Statements

1. The number of repetitions required to reproduce various lengths of material do not increase proportionately with the increase in the length of the material for paired associates. Whether the length of the material be doubled or trebled only a very slight increase in the number of presentations is required for reproduction. Our data seem to indicate that this is true for all kinds of material.

2. The actual time required for learning is proportionately longer than the amount of increase in the length of the material.

3. The general form of the curves is in all cases very much the same for one length of material as for another, and in most cases the memory curves are very much alike even in the lesser details.

Sec. 5. The Effect of Warming Up and Ennui and the Effect of the Time of Exposure upon the Form of the Memory Curve.

This study was suggested by the possibility that some of the differences, especially those in the first and the latter parts of the curves, might be due to the fact that the subject was at first

getting settled and adjusted to his problem or that ennui might influence the learning towards the end or that both these factors might be present in determining the form. For want of a better name, we have used the terms warming up and ennui. It is possible that the form of the curve may change with certain subjective factors; such as, interest, attention, effort, warming up, ennui, and other momentary physiological conditions. If this were true, we should expect to find that, after the subject had been working hard in mastering one series, the curve obtained from a series immediately following would be at least slightly different.

To test this possibility, we gave the subject two series of equal length and of the same kind of material to be learned at one sitting. The second series was given immediately after the first had been mastered. In this way two curves were obtained from each subject at each sitting. Later this procedure was followed with the time of exposure changed from three to one and one half seconds for both series. Our results consequently contain two groups. Group II is the results obtained from curves immediately following those of Group I. Furthermore, these two groups were obtained from some subjects for both three second and one and one half second exposures. In this way results were obtained for two studies at one time. One of these studies, we have, for want of a better name, called the effect of warming up and ennui, and the other the effect of change in the time of exposure.

A. The Effect of Warming Up and of Ennui upon the Form of the Memory Curve.

In table 31, we have first the tabulations of averages from curves of individual subjects in halves, thirds, and sixths of the time or effort expended. Group I and Group II of each subject are placed together in order to facilitate comparison. Following the tabulations for the individual subjects will be found the general averages of the tabulations for each of the groups or series.

These tabulations speak for themselves, and it is evident at once that there is a striking similarity between the curves for the two groups or series. It is possible to say, upon a careful survey

of the averages and the individual tabulations, that in series II there is a slight decrease in the percentages reproduced in the first and last sixth and an increase in the second sixth. This difference is so small, however, that we feel justified in saying that in general there is no real difference between the curves for the two series. If the two factors of warming up and of ennui are present they seem to have no appreciable effect upon the form of the curves for these series of material.

In case of the number of repetitions there seems, however, to be a small decrease in the number for the second series. This decrease may, no doubt be attributed to the effect of warming up from the work on the first series.

B. The Effect of the Time Exposure upon the Form of the Memory Curve.

In the former study this question has already been touched

TABLE 31

Tabulations from Curves of Series I and Series II.

M I = subject M and series I.
MII = subject M " " II, etc.
C = the number of curves from which the tabulations are an average.
P = the average number of presentations.

			Halves		Thirds			Sixths					
	C	P	1	2	1	2	3	1	2	3	4	5	6
3 Seconds													
M I	6	5.8	75.3	24.7	55.1	30.8	14.1	33.1	22.0	20.2	10.6	5.4	8.7
MII	6	4.7	77.0	23.0	54.7	36.5	8.8	31.8	22.9	22.3	14.2	6.1	2.7
1 1/2 Seconds													
M I	6	5.2	71.5	28.5	52.4	28.3	19.3	28.5	23.9	19.1	9.2	10.3	9.0
MII	6	4.8	70.6	29.4	54.8	27.6	17.6	28.6	26.2	15.8	11.8	10.4	7.2
3 Seconds													
N I	6	4.2	77.2	22.8	62.8	23.5	13.7	37.0	25.8	14.4	9.1	7.0	6.7
NII	6	3.5	76.3	23.7	61.9	26.4	11.7	33.1	28.8	14.4	12.0	6.8	4.9
1 1/2 Seconds													
P I	6	3.3	73.7	26.3	58.3	25.8	15.9	29.5	28.8	15.4	10.4	8.0	7.9
PII	6	3.7	70.6	29.4	51.8	36.3	11.9	27.0	24.8	18.8	17.5	6.8	5.1
3 Seconds													
O I	6	5.2	69.9	30.1	58.9	22.9	18.2	36.7	22.2	11.0	11.9	11.3	6.9
OII	6	4.7	80.4	19.6	58.8	29.8	11.4	34.1	24.7	21.6	8.2	5.2	6.2
1 1/2 Seconds													
O I	3	6.0	75.0	25.0	55.5	29.4	15.1	38.0	17.5	19.5	9.9	4.8	10.3
OII	3	5.7	71.5	28.5	54.7	28.6	16.7	31.7	23.0	16.8	11.8	13.3	3.4
General Averages													
Av. I	33	4.9	73.8	24.2	57.2	26.8	16.0	33.8	23.4	16.6	10.2	7.8	8.2
Av. II	33	4.5	74.5	25.5	56.2	30.9	12.9	31.1	25.1	18.3	12.6	8.1	4.8

TABLE 32

Tabulations from Curves of 3 Seconds and 1 1/2 Seconds Exposure.
X = Results from the three seconds exposures.
Z = " " " one and one half seconds exposures.
C = the number of curves from which the tabulations are an average.
P = the average number of presentations required for learning.
Y = the results from the six seconds exposures.

			Halves		Thirds			Sixths					
Sub.	C	P	1	2	1	2	3	1	2	3	4	5	6
Series I													
M X	6	5.8	75.3	24.7	55.1	30.8	14.1	33.1	22.0	20.0	10.6	5.4	8.7
M Z	6	5.2	71.5	28.5	52.4	28.3	19.3	28.5	23.9	19.1	9.2	10.3	9.0
Series II													
M X	6	4.7	77.0	23.0	54.7	36.5	8.8	31.8	22.9	22.3	14.2	6.1	2.7
M Z	6	4.8	70.6	29.4	54.8	27.6	17.6	28.6	26.2	15.8	11.8	10.4	7.2
Series I													
O X	6	5.2	69.9	30.1	58.9	22.9	18.2	36.7	22.2	11.0	11.9	11.3	6.9
O Z	3	6.0	75.0	25.0	55.5	29.4	15.1	38.0	17.5	19.5	9.9	4.8	10.3
Series II													
O X	6	4.7	80.4	19.6	58.8	29.8	11.4	34.1	24.7	21.6	8.2	5.2	6.2
O Z	3	5.7	71.5	28.5	54.7	28.6	16.7	31.7	23.0	16.8	11.8	13.3	3.4
P X	10	3.3	69.7	30.3	55.5	29.2	15.3	32.8	22.7	14.2	15.0	8.2	7.1
P Z	6	3.3	73.7	26.3	58.3	25.8	15.9	29.5	28.8	15.4	10.4	8.0	7.9
P Y	1	3.0	69.5	30.5	52.0	35.0	13.0	26.0	26.0	17.5	17.5	6.5	6.5
S X	6	4.7	68.6	31.4	53.6	28.3	18.1	31.7	21.9	15.0	13.3	9.3	8.8
S Z	3	5.5	69.3	30.7	45.8	39.1	15.1	35.5	10.3	23.5	15.6	11.0	4.1
S Y	4	3.2	62.8	37.2	35.7	51.2	13.1	17.4	18.3	27.1	24.1	7.5	5.6
U X	3	2.7	74.2	25.8	56.4	30.8	12.8	28.2	28.2	17.8	13.0	6.5	6.3
U Z	5	4.6	68.3	31.7	51.7	28.8	19.5	29.2	22.5	16.6	12.2	11.8	7.7
U Y	6	2.2	76.4	33.6	56.3	29.3	14.4	28.2	28.1	20.1	9.2	7.3	7.1
General Averages													
X	43	4.5	73.6	26.4	56.1	29.8	14.1	32.6	23.5	17.5	12.3	7.4	6.7
Z	32	5.0	71.5	28.5	53.4	29.5	17.1	31.6	21.8	18.1	11.4	10.0	7.1
Y	11	2.8	69.6	30.4	48.0	38.5	13.5	23.9	24.1	21.6	16.9	7.1	6.4

upon. The problem here was to find out if, by changing the time of exposure, there would be a change in the form of the curve.

In table 32, we have tabulations for comparing curves from exposures of three seconds with curves from exposures of one and one half seconds. Incidentally we have appended the results obtained with six seconds exposure from three subjects. The data for these are, of course, too limited to be of any real significance; furthermore the curves obtained had to be constructed from so few repetitions that they can represent the general trend of the learning in only the most general fashion.

The tabulations from the curves of the three seconds and the one and one half seconds exposure indicate that there is a very close resemblance between them. Nothing like a real uniform difference for all the subjects is found in any of these results. Some slight differences are found for individual subjects, which, at the most, indicate that the changes in the time of exposure effect the curves for individual subjects, if at all, in very different ways.

The number of repetitions, as they appear in the tabulations show that all except one subject required a larger number of repetitions for learning with one and one half seconds exposure than with three seconds. In nearly all cases, however, only a very slight increase in the number of presentations was required for the one and one half seconds exposure; so that in all cases except one, subject U, the one and one half second exposure was the more economical of the two.

Concluding Statements

1. The factors of warming up and of ennui, as measured in terms of comparing two series of curves the second obtained immediately after the first as a warming up series, do not appear to change the general form of the curves.

2. There is a small decrease in the number of repetitions required in learning a series immediately following another which serves as a warming up or practice series.

3. A variation in the time of exposure does not produce any general change in the form of the learning curve; yet it does produce slight changes in detailed parts of the curves for some subjects.

4. The number of repetitions is not proportional to the time of exposure. The number of presentations required for learning differs very little for exposures of three and for those of one and one half seconds. The one and one half second exposure requires a slightly larger number of repetitions but is the most economical of the two, as far as time is concerned, for the majority of subjects.

IV. SUMMARY AND DISCUSSION

Sec. 1. The New Method of Scoring. (See Summary of Part II, Section 1.)

Since no satisfactory nor accurate method of scoring elements or parts of syllables and numbers reproduced was available, we have formulated a new method based on the results of our subjects. We found that the scoring can be made upon the factual or scientific basis of the number of errors resulting from each part or element. Upon this basis it is possible to evaluate not only parts of these materials but elements and parts of other materials and problems as well.

The well known fact, that, in memorizing a series of any kind of material, the first and last part of the series are learned before the parts in between, was found to be true for our experiment. This principle, however, does not hold for parts or elements of syllables or numbers. Here the order is from the first to the last or from left to right; provided, however, that the elements are equally difficult. The order may be changed if one element, like the vowel in a syllable, is less difficult than the other elements.

The striking uniformity found, in the results of our subjects, in the relative number of errors for the various elements in the materials used, is a good example of certain almost universal tendencies of mental function. (Tables 1, 2, 3, and 4.)

Upon a survey of the experimental results found in these tables, certain questions present themselves. Why should the order of difficulty from less to greater be first, second, and third element of the number or syllable? Why should more errors result from the last consonant than from the vowel and first consonant combined? Why should the vowel, as it does in some of the materials, result in less errors than the first consonant?

To the last question our former discussion has suggested a somewhat positive reply. We are not prepared to give a con-

clusive answer to the first two. More introspective data and more detailed studies will be necessary to answer definitely the why of these questions. Our problems have been problems of what and how rather than why. Still, certain possible explanations suggest themselves. One is the reading habit of grasping elements from left to right. It must be remembered, however, that in reading one grasps words as wholes and the first letter of the word does not necessarily receive the maximum of attention. It seems, therefore, that if this habit should play a part, it can not be taken as a full explanation. The fact that the last consonant is the most difficult suggests that somehow it does not receive the emphasis and attention given to the other elements. Herein, no doubt, will be found the main reason. It seems probable that visual, auditory, and kinaesthetic imagery may give more emphasis to the first part of the syllable. The first consonant naturally receives the most emphasis when the subject tries to tie the syllable to its preceding associate. Visually it is nearer to the associate syllable; auditorily, whether audibly pronounced or not, it with the vowel gives the sound to the syllable; and kinaesthetically it receives the emphasis in the pronunciation of the syllable whether the vocalization be actual or merely felt. Auditorily and kinaesthetically it is very probable that the last consonant receives very much less emphasis than the first. These factors, it seems to us, may be in part the cause of the relatively larger number of errors from the last consonant.

Sec. 2. The New Methods of Grouping, Presenting, and Comparing Results. (See Part II, Sec. 2.)

Our methods of grouping, presenting, and comparing results are briefly as follows:

a. Drawing of graphs or curves from the results of each individual group of material learned or problem mastered. These graphs are drawn such that their abscissae are equal in length no matter how many repetitions are required or how long a time is needed for learning.

b. Having these curves, it is possible to select any common point in each of them and thus compare the fractional parts

mastered at various intervals of the learning by comparing the numerical values of these points. The numerical value of any particular point in the curve can be determined by its distance from the abscissa or base line.

c. Tables are constructed in which each curve is represented in numerical terms corresponding to the points of the curves selected for comparison. These points may be halves, thirds, sixths or any other fractional parts of the learning.

d. This method makes it possible to compare curves of any kind by comparing points in which all the effort represented is properly distributed in the graphs of the same.

e. Curves, thus represented, are amenable to numerical computation and statistical methods for various purposes.

This method should be valuable particularly in cases where a large number of curves have to be brought together for comparison and where one may wish to combine a large number of curves into one common curve.

Sec. 3. The Number of Repetitions Required for Learning. (See Discussions and Summaries in Part III, Experimental Results. Sections 1, 2, 4, and 5.)

The facts obtained, relating to the number of repetitions required for learning, were incidental to our main problem; but they are so suggestive and so closely related to it that a brief discussion of them can not be omitted.

The facts adduced from our experimental results, as shown in the study of the effect of practice, Part II, Sec. 1, indicate that there is a very marked reduction in the number of repetitions required for learning after practice. This is in accord with the results of others. In the following table a comparison is made between the results given by Meumann and our own. We have taken the averages from the results of the four subjects reported by Meumann.[1] His subjects practiced on series of 16 nonsense syllables. In the table these can be compared with the averages from our subjects with four different kinds of materials. (See also Graphs, Plates I, II, and III.)

[1] Meumann, E., The Psychology of Learning, page 358.

TABLE 33

	Material	Number of Subjects	Repetitions Before Practice	Repetitions After Practice
Meumann	16 syllables	4	27.0	5.2
Kjerstad	12 syllables	1	18.0	4.0
"	12 Pairs	4	19.0	5.5
"	9 Number-syllable	3	22.0	6.7
"	18 Paired Meaning	2	3.5	2.5

The table shows quite clearly that a very large reduction in the number of presentations does result from practice. The amount it will be seen, depends upon the kind of material learned. In general, we may say that the more familiar the material happens to be the less will be the reduction. Furthermore, while the effect of practice is in a large measure specific for each particular kind of material, it, nevertheless, does have a marked influence upon other materials somewhat similar in nature. For instance, after practice upon paired number-syllable material, the subject will not require so many repetitions for learning paired nonsense material. Subject M is an example of this. (See Graphs, Subject M, Plate III.) This fact shows that the subject is able to carry over a part of the practice effect from one kind of material to another somewhat similar. No one will deny that transfer of this kind does take place. What is carried over in this case is, no doubt, methods or habits of attacking the material to be learned.

In the study of individual differences (Tables 17-25), we found that subjects vary a great deal in the number of repetitions required to reproduce the same material. Some subjects required as much as three times the number of repetitions used by others.

The same lack of uniformity is found in the different kinds of material. (Tables 27 and 33.) The number-syllable material in most cases seems to take from three to four times as many presentations as the paired meaning material. The causes for these differences are, no doubt to be found mainly in the greater complexity and the greater lack of meaning in the number-syllable material.

In the study of the effect of warming up on the number of presentations required, we found that, in learning a series fol-

lowing a warming up or practice series, there was a general tendency to decrease slightly the number of repetitions required for the second series. (See Table 31.) This indicates, what is commonly observed, that it takes the subject some time to get settled down and adjusted to the problem of memorizing before he can learn most effectively each day.

The time of exposure might be supposed to have a very marked influence upon the number of presentations. The results show that it has some influence, but the number are by no means proportional to the time of exposure. (Table 32.) It is clear that changing the exposure from three to one and one half seconds or vice versa results in only a very slight change in the number of presentations. The change in the time of exposure is, therefore, relatively much greater within certain limits than the change in the number of repetitions.

In the study of the effect of the length of the material upon the number of presentations, we found that the number do not increase progressively in proportion to the increase in the length of the material. (Tables 28, 29, and 30.) Here our findings are the very opposite from those reported by Ebbinghaus.[2] Ebbinghaus formulated the law that the larger groups of material require a disproportionately larger number of repetitions. "The number of repetitions necessary for memorization of series in which the number of syllables progressively increased, itself increases with extraordinary rapidity with the increase in the number of syllables."[2] This, it is clear, is the opposite from our facts. Our results force us to agree with Meumann who maintains that the law promulgated by Ebbinghaus does not hold. Meumann's own investigations do not agree with those of Ebbinghaus and he reports that Weber, who worked in his laboratory at Münster "discovered that the law of Ebbinghaus is valid only for unpracticed learners."[3] In the following table, table 34, we quote the results from Ebbinghaus,[2] and those from Meumann,[4] as well as those from our own subjects for four different materials. (See also Table 30.)

[2] Ebbinghaus, I. H., Memory, Ruger translation, pp. 47, 48.
[3] Meumann, E., The Psychology of Learning, p. 275.
[4] Meumann, E., The Psychology of Learning, p. 276.

TABLE 34

Number of Syllables	Number of Repetitions				
	Ebbinghaus	Meumann	Kjerstad		
			Serial Syllables	Paired Syllables	Paired Meaning
7	1.0	—	—	—	—
8	—	5.2	—	—	—
12	16.6	10.4	4.8	6.5	5.0
16	30.0	17.0	—	—	—
18	—	21.5	6.1	7.6	6.7
24	44.0	30.0	—	7.7	—
36	55.0	32.5	—	8.7	—

Ebbinghaus calls attention to the fact that he had the results from only one subject, i.e. himself; Meumann does not state the number of subjects concerned in his results but we take it that there were several; in our own, we have included the results of only two subjects in the serial nonsense material, four in the paired nonsense, and only one in the paired meaning material. We have confined ourselves to this limited number of subjects because they are the only ones for whom we are certain that the practice effect had been eliminated before these results were taken. These results are, however, confirmed by the results of our other subjects who had less practice. (See Table 17-24, 29, and 30.) It is clear, however, that no valid conclusions can be drawn from unpracticed subjects, since the practice effect from one length of material would be carried over to the following length of material used.

It is evident that our results point conclusively to an opposite conclusion to that of Ebbinghaus. With the increase in the length of the material there is only a very slight increase in the number of repetitions required as is shown by the results of our practiced subjects. At the same time, our results are quite different from those in Meumann's table. How are we to explain this difference?

The number of presentations reported in Meumann's table are entirely too large to be from practiced subjects. As already mentioned, we do not know just where or how he obtained them. The only information he gives is found in the sentence preceding his table. "Our pupils are on the whole practiced learners; and with practiced learners we always found a confirmation of the

law . . . which may be illustrated by the following data:"[5] After this he gives the tables of results cited above. The expression, "are on the whole practiced learners," seems to indicate that they had not been subjected to controlled practice before the data in the table were obtained. Almost conclusive proof, that his subjects were not practiced subjects is found in his discussion on the effect of practice in which are found the following tables taken from his own text.[6]

The limited number of repetitions shown after practice by Meumann's subjects in both the ten and the sixteen syllable material agree very closely with the number of presentations for our subjects given in table 34. It would seem, therefore, that, if Meumann had used practiced subjects, the 17 repetitions shown for the 16 syllable material should have been reduced to about 5.2 which is the average for his practiced subjects. Our practiced subjects used 6.1 presentations for the 18 syllable material. It is interesting to note that Meumann's subjects used on the average just as many repetitions before practice in the 10 as in the 16 syllable material.

It seems, therefore, that the increase, in the number of repetitions for practiced subjects, is even less in proportion to the increase in the length of the material than Meumann's results would indicate.

It must be remembered that the very slight increase in the number of presentations for the longer materials does not mean that proportionately less time is used for longer material than for shorter. Table 30, from our results, shows that, although

TABLE 35[6]

		Repetitions	
	Observers	Before practice	After practice
10 Syllables			
	Ba	28	3
	F	23	2
	Br	25	4
	M	31	4
16 Syllables			
	Ba	31	5
	F	19	5
	Br	23	8
	M	34	3

[5] Meumann, E., The Psychology of Learning, pp. 275-6.
[6] Meumann, E., The Psychology of Learning, p. 358.

the number of repetitions are but slightly increased for the longer materials, the actual time taken for learning is proportionately longer than the amount of increase in the series or material. This fact seems to have been overlooked by Meumann in his interpretation when he says: "At the same time, the slow increase in the number of repetitions with the increase in the amount of material reveals the presence of a fact of will, and also perhaps an attitude or adjustment, which may be described by the statement that the expenditure of energy is regulated automatically to conform with the magnitude of the achievement which is demanded of the learner."[7] If Meumann had measured the energy used in terms of the actual time consumed, as we have done, it is doubtful if he would have found it necessary to resort to his "universal law of will" for interpretation. For us there is no longer anything to interpret. Our subjects actually had to use more time proportionately for the longer material, (See Table 30), which is to be expected from a common sense point of view.

More recent and more extended studies of this problem have been made by V. C. N. Henmon[7a] and D. O. Lyon[7b]. A brief statement of their results is found in a recent publication by D. O. Lyon.[7c]

In the following table (Tables C to J) we reproduce their results on nonsense syllables.

[7] Meumann, E., The Psychology of Learning, p. 277.
[7a] Henmon, V. C. N., Journal of Experimental Psychology, Vol. II.
[7b] Lyon, D. O., Relation of Length of Material to Time, Journal of Educational Psychology, Vol. V, 1914.
[7c] Lyon, D. O., Memory and the Learning Process, 1917. Warwick & York.

TABLES C TO J

No. of Syll.	C Meumann Rep.	D Ebbinghaus Rep.	E Henmon Rep.	F Henmon Rep.	G Lyon Rep.	H Lyon Rep.	I Lyon Rep.	J Lyon Time
8	5	1	—	—	—	5	4	¼ min.
10	—	—	7	13	144	—	—	—
12	10	17	8	14	—	69	60	6 mins.
14	—	—	8	15	—	—	—	—
16	17	30	9	15	—	83	67	9 "
18	21	—	11	16	—	—	—	—
20	—	—	14	19	138	—	—	—
24	30	44	13	16	—	94	80	16 "
30	—	—	20	26	—	—	—	—
32	—	—	—	—	—	103	105	28 "
36	33	55	—	—	—	—	—	—
40	—	—	—	—	174	—	—	—
48	—	—	—	—	—	120	107	43 "
72	—	—	—	—	—	306	230	138 "

Tables C, D, and E are averages of several trials—self as subject.
Table F is an average of 3 experiments on one subject.
Table G is an average from 14 subjects—approximate only.
Table H is an average of two experiments on one subject.
Table I approximate only.
Table J taken from Plate I, Memory and the Learning Process by D. O. Lyon.

The table shows, as we have already indicated, that the number of repetitions required in memorizing is quite variable and dependent on a large variety of factors. It is evident that extreme care must be exercised in experiments on this problem if comparable results are to be obtained. The best that can be said at present, it seems to us, is that the number of repetitions and the time taken varies with practice, individual concerned, kind of material, length of material, and other momentary factors.

Sec. 4. The Learning Curves for Memory.

It is not our purpose to attempt a complete interpretation of the forms of the curves obtained. Our problem was to find out whether or not the curves for memory tended towards a common form under changing conditions by introducing as many factors for variation as the limit of our research would permit. We have not begun to introduce all possible factors, but the factors we have introduced will serve as a basis for hypotheses in regard to the probabilities of others.

We have seen that with reference to the number of repetitions

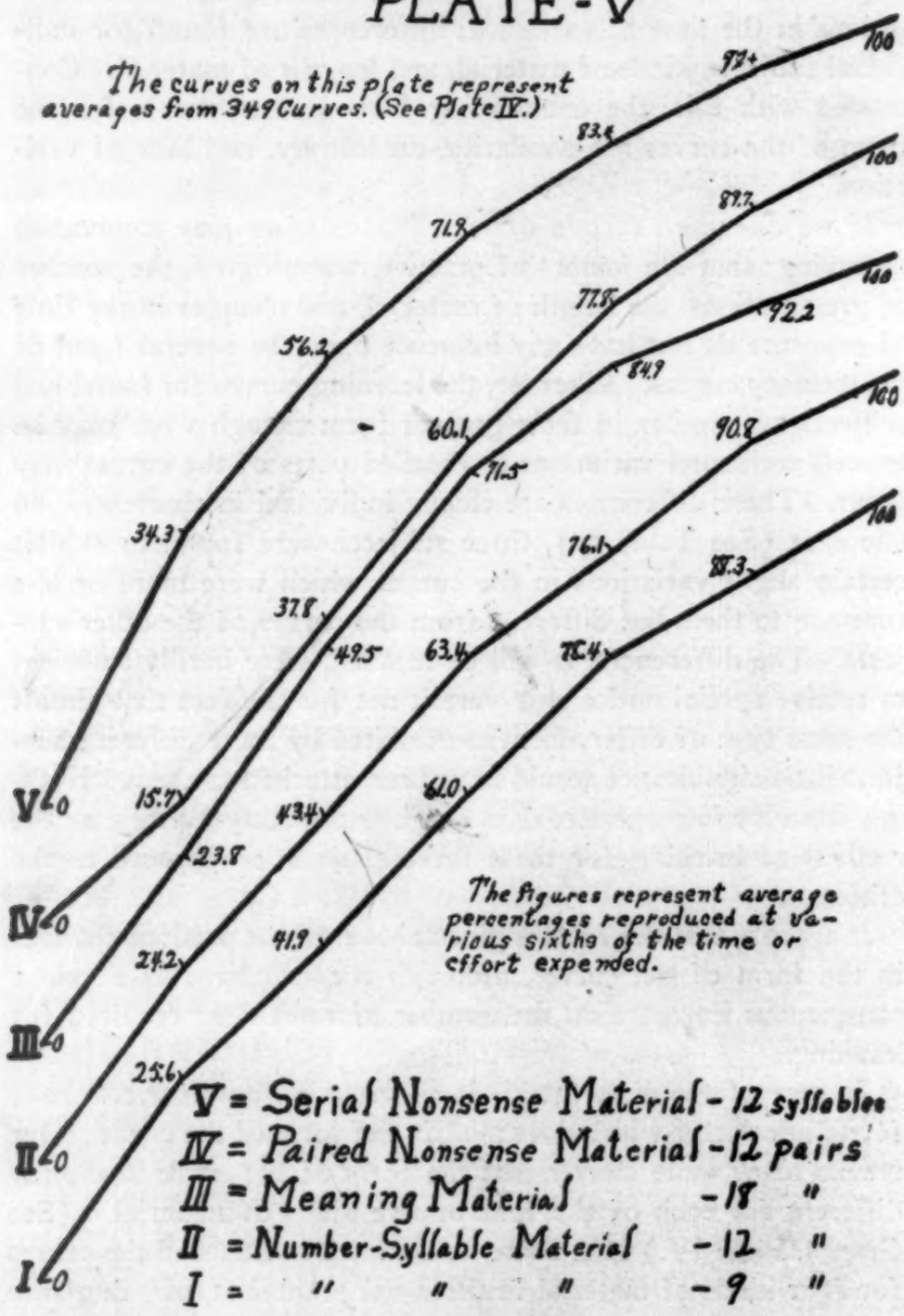
the outstanding fact is the fact of variation, change, and difference. Change results from practice, warming up, and modifications in the time of exposure; differences are found for individual subjects, kinds of material, and lengths of material. Contrasted with this, the outstanding facts in our results for the form of the curves are similarity, uniformity, and lack of variation.

If we disregard certain minor variations, we may summarize by saying: that the factors of practice, warming up, the number of presentations, the length of material, and changes in the time of exposure do not have any influence upon the general form of the memory curves. Likewise, the learning curves for individual subjects are similar in their general form though what may be termed accidental variations in detailed parts of the curves may occur. These differences are chiefly individual in character. In one case (See Table 17), three subjects were found to exhibit certain slight variations in the curves which were more or less common to them but different from the curves of the other subjects. The differences, it will be recalled, were hardly sufficient to receive special notice and were it not for the fact that almost the same type of difference was exhibited by three different subjects little significance would have been attached to them. Nothing from the introspective data suggests anything different in the method of learning for these three subjects as opposed to the others.

It appears that the factors given above do not produce changes in the form of the curves, although they do have as a rule a conspicuous influence on the number of repetitions required for learning.

In case of the different kinds of material, however, we have found one factor which does modify the form of the curve. Our results show quite clearly that the form of the curve is slightly different for each of the four or five kinds of material. (See Graphs, Plate IV.) On Plate V, we have constructed the curves for four kinds of material in the usual graphic form. A glance at these will show the reader at once why we have refrained from this method of representing the curves. Even here, where we

PLATE-V


The curves on this plate represent averages from 349 Curves. (See Plate IV.)
V
IV
III
II
I
0
15.7
34.3
56.2
72.4
83.6
100
23.8
37.8
60.1
71.8
87.7
100
24.2
49.5
71.5
77.8
92.2
100
41.9
63.4
84.9
90.8
100
25.6
43.4
61.0
76.1
88.3
100
The figures represent average percentages reproduced at various sixths of the time or effort expended.
V = Serial Nonsense Material - 12 syllables
IV = Paired Nonsense Material - 12 pairs
III = Meaning Material - 18 "
II = Number-Syllable Material - 12 "
I = " " " - 9 "

maintain that we have a real difference in the curves, it seems that they are so much alike that we may be accused of insisting on too fine distinctions. The reader is referred again to the graphs on Plate IV and the diagrams in Table 26 and Table 27. When comparisons are made in these figures, diagrams, and graphs, the reasons for our maintaining a real difference between the form of the curves for these materials will be evident. *It is not the amount of difference that is significant so much as it is the uniformity with which this occurs for the various subjects and under other varying factors. This fact makes the difference a real, valid, and significant one.* In fact differences, that occur *constantly* under the most varying conditions, are magnified rather than belittled by their minuteness.

Although the main purpose of our study or investigation has not been directed towards accounting for differences, yet some suggestions are pertinent. Unfortunately we have to pioneer in the study of this particular type of learning curves, i.e. memory, and can not get much direct assistance from other sources for interpretation of results.

While little or no attempt has been made to study memory curves, there is a very extensive literature on practice and learning curves of various types. It would not be wise to attempt a review of these at this time. For this the reader is referred to other sources. These memory curves, however, indicate that they have much in common with other learning and practice curves. This is true not only of the general form of the curves but of the factors causing variations in the form.

In a study made of the learning curves for typewriting, we found, as we have found in this study, that the principal factor in changing the form of the curves was the particular kind of material to be mastered. This is an unpublished study (Master's Thesis), made of typewriting curves from four subjects for whom typewriting was a new experience. These subjects carried on practice for a period of one half hour per day for a period of about three months. Ten minutes of this time was given over to practice on a practice sentence, immediately following this twenty minutes were given to practice in taking

copy. Two curves were thus obtained from each subject, one from each kind of practice or material practiced upon. In view of the results in our present study of the effect of different kinds of material the following quotations from the summary may be of interest.

"4. There is no correlation between the practice sentence and the copy learning of each subject in gain or loss in speed for the individual practice periods.

"5. There is no significant correlation between the practice sentence and the copy curves in their general features.

"6. There is very little, and on the whole, an insignificant correlation between the practice sentence and the copy learning in periods of rapid advance and periods of little or no advance.

"7. There is no correlation between the practice sentence and the copy learning of each subject, either in kind of errors or in the increase or decrease in the per cent of error for each day's practice.

"8. There is a rather marked correlation between the practice sentence curves of the four subjects in their general course and features.

"9. There is similar marked correlation between the copy curves of the four subjects as to their general course and features.

"10. There is a rather striking correlation with reference to the speed levels at which difficulties occur in all curves."[8]

These results for practice curves of typewriting are interesting in that they show that the kind of material to be learned has a marked influence upon the practice or learning curve for these, just as the kind of material seems to be the principal factor for variation in the memory curves. This suggests that the memory curves have many points in common with the curves for typewriting. The following quotation is as applicable to our present study as it was to that of the results for the typewriting study. "The correlation, found in the results of our experiments, between the curves of different subjects, both as to their general and their periodic features, *indicates that the causes for*

[8] Kjerstad, C. L., A Study of the Form and the Fluctuations in the Learning Curves for Typewriting, p. 43. Univ. of Chicago Library.

these fluctuations must be sought in factors peculiar to the particular type of learning rather than in any changeable physical or mental subjective conditions that may be involved."[9]

Two general features of our curves require specific discussion. These are the initial rise in the curves and the gradual flattening of the curves toward the upper end or what Thorndike calls negative acceleration. These, however, may be said to be one and the same feature, so that they may well be discussed together. Both these features seem to be found in most learning curves. Some exceptions are found, as the ball tossing curves of Swift.[10] The following from our former study is applicable again. "It would appear then, that this rapid initial rise may not be a necessary feature in all types of learning. Furthermore, it may vary with individuals, and always varies with the kind of learning involved. The more interesting fact is that it seems to be more or less similar in learning of the same kind even for different individuals."[11]

Why this rapid initial rise and why this negative acceleration where it does occur in the learning curves for memory?

For some practice curves, fatigue has been suggested as an explanatory factor. This can hardly be a factor in memory curves since one curve obtained immediately after another was found to be similar in form. (Table 31.) Book suggests interest and attention as factors.[12] Again the results found in Table 31 and the variations in the curves for different materials do not indicate such an explanation for memory curves. That under certain conditions they are contributary factors there can be no doubt, but we are quite convinced that in most cases they are minor factors in determining the form of the curves.[13]

Without stopping to comment upon each, the following quotations will serve to bring other suggested factors before us.

"The first rapid and continuous rise is due to the fact that the learner is making progress along many different lines at once.

[9] Kjerstad, C. L., Op. cit., p. 82.
[10] Swift, E. J., Mind in the Making, pp. 174, 175.
[11] Kjerstad, C. L., Op. cit., pp. 68, 69.
[12] Book, W. F., The Psychology of Skill, pp. 99, 100.
[13] Kjerstad, Op. cit., pp. 68, 69.

. . . Every man has experience with the first stages of learning, but little with the later stages because most people touch lightly many things and are masters of nothing."[12]

"It now becomes clear that in so far as the beginning of practice of any mental function means a beginning with the aid from many acquisitions already made in life and from the instinctive bonds that life so far has allowed to act, there are likely to be existing bonds which with slight amendment serve the new function's ends, which will be brought into service early rather than late; and so help to produce the so common early rapid rise."[14]

"The superficial grasp of a few elements that did very good service at first when everything was simple, no longer meets the requirements. The details have greatly increased in number and their loose connection is easily broken. As a result they soon fall into confusion."[15]

The following factors were brought out and emphasized in our former study. "It appears then that we may be making trouble for the future in at least four different ways: (1) by adopting definitely fixed complexes not originally acquired for typewriting use; (2) by adopting useless and wrong complexes; (3) by acquiring smaller and larger complexes which, though useful at a certain stage, become useless and impede the progress in learning in a more advanced stage; (4) by falling into the general habit of writing at a certain more or less definite speed because we do not try to force ourselves ahead."[16]

Each of the above factors are suggestive and, no doubt, play a part in the form of at least some of the learning curves. They also suggest what may be some of the factors for memory curves. In case of these, it is quite certain that the relative difficulty of different parts of the material play a very large part in determining their form. The subject naturally will master the least difficult associations first. In the first presentation, the subject, no doubt, finds certain associations appearing quite readily and these are pounced upon and kept in mind for reproduction. Later the

[14] Thorndike, E. L., The Psychology of Learning, p. 282.
[15] Swift, E. J., Mind in the Making, p. 211.
[16] Kjerstad, C. L., Op. cit., p. 85.

subject has to make use of forced associations and often has to depend upon pure visualization for reproduction. Our introspective data show clearly that in most cases the first syllables reproduced were those for which certain meanings at once suggested themselves to the subject. Most of these naturally came in the early part of the learning. The difference in the curves for various kinds of material strongly suggest this explanation. In case of the number-syllable material, the number elements would be all of nearly equal difficulty. This material, being more homogeneous, would not give opportunity for certain parts to be easily mastered at first and this would result in less negative acceleration, which is exactly what we find. These curves, it will be remembered, approach more nearly to a straight line than the curves for the other materials.

But how are we to account for the novel lack of the "rapid initial rise" in the paired nonsense material which we know permitted more meaning on the whole than the number-syllable material? And why should the most conspicuous initial rise be found in the serial nonsense material?

This, we think, can be accounted for by another factor. It is clear that no effect will be produced upon the score until the learning is complete enough for reproduction. In case of the serial syllables, the subject was permitted to spread his attention and effort upon any part of the series during the presentation, hence he would be able to go back and repeat the least difficult syllable again and again during the presentation, or he could concentrate upon a certain group of syllables. In either case, he would be able to give a good account of himself at the first attempted reproductions. In case of the paired material, however, the subject was commanded to drop each pair from his mind entirely as soon as the next pair was presented and under no conditions to attempt to refer back to any pair or syllable until the associate was presented. This method gives an ideal condition for part but incomplete learning and would result in the poor showing made in the early part of the learning as indicated in the curve.

But, it will be objected, why then do we not have the lack of

the rapid initial rise in the paired number—syllable material and the paired meaning material? This question can be answered by interpolating another factor, namely novelty. Words and numbers were not new experiences for our subjects in the sense that nonsense syllables were. Our subjects told us repeatedly that at first some of the numbers were quite easy to remember because they suggested dates, street numbers, or post office box numbers; while others simply had to be remembered by "sheer force" which they contended was an "awful" task when given only three seconds in which to concentrate upon them. In case of the nonsense syllables, it is different. Here each individual of the pair was new to the subject and it required some time before they could be fixed in the mind. The subjects often said that they were just getting acquainted with the syllables. In other words recognition was making itself felt but there was no reproduction.

In these three factors relative difficulty, incomplete learning, and novelty, we may have at least a partial explanation of the forms of the memory curves and their variation for the different kinds of material. To these, we would add at least two more, which are likely most effective for the latter half of the curve. These are wrong associations and what may be called the habit of not being able to recall an associate syllable or number. Very often our subjects habitually associated the wrong syllables, words, or syllables and numbers such that, though they saw the correct associates visually at each presentation, it would not be carried over to reproduction. Consequently, when the test associate was given the habitually wrong syllable was reproduced. So strong was this tendency or habit that occasionally a subject offered to swear to the correctness of his reproduction. It is clear that, due to the repetitions added to correct errors of this kind, a flattening of the curve would result at the end. The other factor, which we have called the habit of not reproducing a syllable or an associate, is also present in the latter half of the learning. This is analogous to what we, in the case of typewriting, called the habit of writing at a certain uniform speed which may be continued for days or even for weeks. In case of memorizing, however, this might be better characterized as the

factor of inhibition. The subject seemed to remember that he did not know a certain syllable and had a questioning attitude as soon as the time came for him to reproduce it. He seemed to try to call to mind the missing syllable but failed in spite of his effort. This holding back of one or two syllables or numbers at the end of the learning would naturally lengthen and flatten the curve towards the end.

These are the main factors, as we see them, which may explain the facts of initial rise and of negative acceleration as they appeared in the learning of our subjects, and consequently in the memory curves. *The unusual feature of the most rapid rise appearing near the mid point of the curves, as it does in the learning of paired associates of the nonsense material, may also, as we have seen, be accounted for by the interaction of these factors. At first the result on the score will be small on account of the method of presentation and the consequent partial but incomplete learning, later when the partially learned syllables begin to be reproduced they will be reproduced all along the line resulting in an unusually high score, then as the number of possible means of scoring decreases and inhibitions and wrong associations begin to make themselves felt on the score negative acceleration is the result.*

The factors given above should not be taken as an exhaustive analysis of the *why,* which is subsidiary to our main problem.

In conclusion, we wish to call to mind once more the results between the facts of variation and change as found in the results for the number of repetitions on the one side, and the facts of uniformity and likeness as found in the form of the memory curves on the other.

These facts suggest to us, what probably does not receive enough attention from some of our present day psychologists, that deeply rooted in the human mind, physically or psychically or both, are found certain innate, basic, and *universal common* elements which issue in more or less definite and general modes of functioning; and that upon this, the selective process of experience lays its moulding hand which does putter and change very markedly indeed the detailed mode of expression but cannot modify its innate fundamental aspects.